

# MOTORCYCLE TOW DOLLY

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by

Justin T. Koeth

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Thesis Advisor: Professor Ahmed Elgafy, Ph.D.

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**ABSTRACT**

Based on the research gathered from other products, an idea could begin to form of product objectives would improvements to the current technology or new ideas could be incorporated into the design project. Then the research from a survey, which included a variety of product objectives, the most important product features could be determined and concept designs could be created.

Two concept designs were required for the design project in order to allow a variety of products. By creating a variety of designs and weighing them back with the survey results mentioned earlier in a QFD, the best design concept arises in an unbiased form. This design can then be properly designed and redesigned with the stresses that it will undergo in order to create a functional product ready for manufacturing.

## **PROBLEM DEFINITION AND RESEARCH**

### ***PROBLEM DEFINITION AND BACKGROUND***

Many people have motorcycles and take them for long trips to places built for riding, such as the famous 'The Tail of the Dragon' in North Carolina. This is not a problem for those with cruiser-type motorcycles; unfortunately, there are many varieties of motorcycles sold today that are not easily rideable for extended periods of time. People that have trucks or trailers can transport one easily, but not everyone has these types of vehicles or have the monies to afford them.

The proposal for my senior design concept is to create a motorcycle tow dolly that attaches to the 1.25" Class I car hitch to lift up the front tire to tow the motorcycle to provide an inexpensive means of transporting various 2-wheel vehicles. There are few products on the market today, and the ones that are for sale, all have 2" receivers. There is an option to use an adapter to allow the smaller receivers to fit the current market tow dolly's; however, the added weight of a 1.25" to 2" adapter and the low car hitch height causes low clearance problems when attempting to use such a configuration. An inexpensive motorcycle tow dolly that solves for these two problems, while improving on the current idea by adding customer focused features, could appeal to those with commuter scooters/motorcycles that lack the money to purchase an expensive trailer or truck to transport said vehicles (1).

### ***RESEARCH, TECHNOLOGY, AND EXISTING PRODUCTS***

Some of the findings from my research shows that many are not very concerned about a state of the art method for transporting their motorcycles/scooters. Many of the reviews of current market products reveal that there is no product at a lower price point that is considered satisfactory. They are more concerned with having an inexpensive yet durable product that can be used without much modification. This means that they are more so looking for a proven product and are not looking for something that will revolutionize or change the industry. As there are not many of these types of products on the market at a low price point, there is quite a bit of room for improvement with the current technology.

**RESEARCH*****PRODUCT #1 - DANDY HAULER, A MOTORCYCLE CARRIER***

Figure 1 - The Dandy Hauler (2)

This design shows a plan for rigidity and simplicity. It is completely fixed design does not allow for great flexibility or the ability for a wide range of tire sizes. This product allows for increased stability for the motorcycle by including a tie down bar located near the top of the fixture to allow for straps to keep the handlebars in a locked position. This design is for a Class II or III, 2.00" hitch receiver. This allows for greater tongue and tow capacity relative to the goal of this design project. It does not fold, however the top tie down bar is removable. This design appears practical for those with dual sport motorcycles as they typically have smaller front tires. It is rather lightweight, coming in at 26 pounds with the tie down bar and 21 pounds without. There is not a weight capacity for this product listed (3).

***PRODUCT #2 – THE ORIGINAL SLICK WHEELIE MOTORCYCLE HAULER***

Figure 2 – The Original Slick Wheelie Motorcycle Hauler (4)

This motorcycle receiver hauler only supports only Class II or III type hitch receivers. The design has a crank that lowers to the ground to allow the motorcycle to drive up on the fixture before it is then raised. The unit is a bit heavier at 32 pounds. This design appears to accommodate motorcycles with a larger front wheel, however; will not work with tires greater than 5.5" wide. This design does allow for disassembly for more compact storage. This device does not require pushing a bike up a ramp, which can be appealing to the consumer, and it is rated to handle motorcycles with a curb weight of up to 1000 pounds (4).

***PRODUCT #3 – TMS MOTORCYCLE TRAILER HITCH CARRIER***



Figure 3 – TMS Motorcycle Trailer Hitch Carrier (5)

This design features an easy lifting feature using the leverage of the bar to raise and lower the main tire cradle, which is then locked in place with pins. This product weighs 30 pounds and is also built for Class II and III type hitch receivers. With a capacity of 800 pounds and a wide tire cradle, it is able to accommodate most motorcycles. This design does not have handlebar tie down bars, but has some great features with a rather simple design, such as the lower wheel rocker to allow for easy front tire mounting and the adjustable cradle for various tire sizes and heights (5)

### ***CUSTOMER PROFILE***

The motorcycle tow dolly that I am proposing would be directed to a specific customer as it solves a problem that not everyone would have. First, the market for a product like this would only include those with a car with a hitch that would like to tow their scooter, motorcycle, or dirt bike. This would likely mean that they are not capable of paying large amounts of money for a trailer to pull the motorcycle or do not have a truck with which they can carry a motorcycle in the bed. The budget for this product will likely be low according to these types of customers. The gender of many customers is likely to be male, as there are many more men that ride motorcycles, scooters, and dirt bikes than females (6). The age group that would be in the market for a product like this will likely be a younger age such as 20 – 30, as many of them would not have time or money to purchase all the equipment needed to tow a motorcycle with traditional trailers. People living in rural areas are more likely to use this product because they would most likely need to move their motorcycle or scooter to a farther location as opposed to someone who lived in a city. This is also true because many more people own motorcycles in the suburbs and rural areas as it is often easier to ride in those areas and it is often dangerous to ride in the city with heavy traffic. The skill level of the customers is likely to be high as many are likely to know about how their motorcycle works as they often need repairs and more routine maintenance than cars. This means that they should know generally how the product works, without the need for very detailed diagrams/instructions for the product.

### ***SURVEY ANALYSIS***

The survey that was conducted for those that were interested in potential solutions that the design project could provide. The product features were based off the research from the current market products and reviews in order to determine all possible features a customer would expect when in the market for this type of product. The results from Table 1 show that functionality, durability, and reliability/motorcycle security are the top items that users look for when transporting a motorcycle by means other than actually riding it. This makes sense as motorcyclists are often concerned for their expensive vehicles when taking them from one place to another, and if a product does not deliver on these main principles will result in a cost much greater than the product itself. The design selected was based on these main principles and will consider all customer features while also attempting the main goal of using a Class I hitch to carry a motorcycle with a curb weight of 400 lbs or less. Table 2 is also important to consider as it shows how customers are satisfied with the current market products (any motorcycle transport system). It is apparent that they are not as pleased with the storage size and weight of current products, this aligns with this design project in order to deliver a small and lightweight tow dolly that can be used by any vehicle that supports hitch carrying capabilities.

Table 1 – Customer Feature Importance

Customer Feature	Importance	Relative Weight
<i>FUNCTIONALITY</i>	4.56	11.42%
<i>DURABILITY</i>	4.33	10.86%
<i>RELIABILITY</i>	4.22	10.58%
<i>MOTORCYCLE SECURITY</i>	4.22	10.58%
<i>PRICE</i>	4.11	10.31%
<i>SETUP TIME</i>	4.00	10.03%
<i>LIFETIME OF PRODUCT</i>	3.89	9.75%
<i>CORROSIVE RESISTANCE</i>	3.89	9.75%
<i>CARRYING CAPACITY</i>	3.33	8.36%
<i>STORAGE (SIZE AND WEIGHT)</i>	3.33	8.36%

Table 2 – Customer Current Product Satisfaction

Customer Feature	Current Product Satisfaction	Relative Weight
<i>SETUP TIME</i>	3.44	11.88%
<i>FUNCTIONALITY</i>	3.33	11.49%
<i>LIFETIME OF PRODUCT</i>	3.11	10.73%
<i>RELIABILITY</i>	3.00	10.34%
<i>PRICE</i>	3.00	10.34%
<i>MOTORCYCLE SECURITY</i>	2.78	9.58%
<i>CORROSIVE RESISTANCE</i>	2.78	9.58%
<i>DURABILITY</i>	2.67	9.20%
<i>CARRYING CAPACITY</i>	2.56	8.81%
<i>STORAGE (SIZE AND WEIGHT)</i>	2.33	8.05%

### ***PRODUCT OBJECTIVES***

- **Functionality**
  - Number of designed features that are used by the customer in order to aid in the use of a product such as tie down locations for handlebars.
- **Durability**
  - The enduring qualities of a product. Designed to resist wear and tear from possible road debris.

- **Reliability**
  - The ability for the product to perform as it is intended by meeting customer and design specifications time after time. Intended to be used when transporting a motorcycle long distances.
- **Motorcycle Security**
  - Added safety features and stability when operating provide increased safety for the product, such as tie down straps or locking mechanisms.
- **Price**
  - Costs for material and manufacturing labor directly reduce the cost that can be forwarded to the customer such as designing using standard material sizes.
- **Storage (Size and Weight)**
  - Possible to disassemble the product into a smaller footprint than the size of the product in its usable state.
  - Lightweight in order to allow easy storage and setup, under 45 lbs.
- **Setup Time**
  - Short amount of time to remove from the product storage and setup the product into a usable state. Be able to raise or lower motorcycle quickly.
- **Corrosive Resistance**
  - Protected against weather elements that may damage the equipment or product over a long period of time by painting or protecting equipment.
- **Lifetime of Product**
  - Built for a designed number of hours, with the expected number of uses in mind. Expected to last at least 10 years.

### ***ENGINEERING CHARACTERISTICS***

The results from the Table 1 were then used to create engineering characteristics for a product that we might see today. These characteristics were then compared with the customer features in Table 1 by using a quality function deployment matrix (QFD). This QFD aided in determining which engineering characteristics were most critical when designing the motorcycle tow dolly. From Table 3 below,

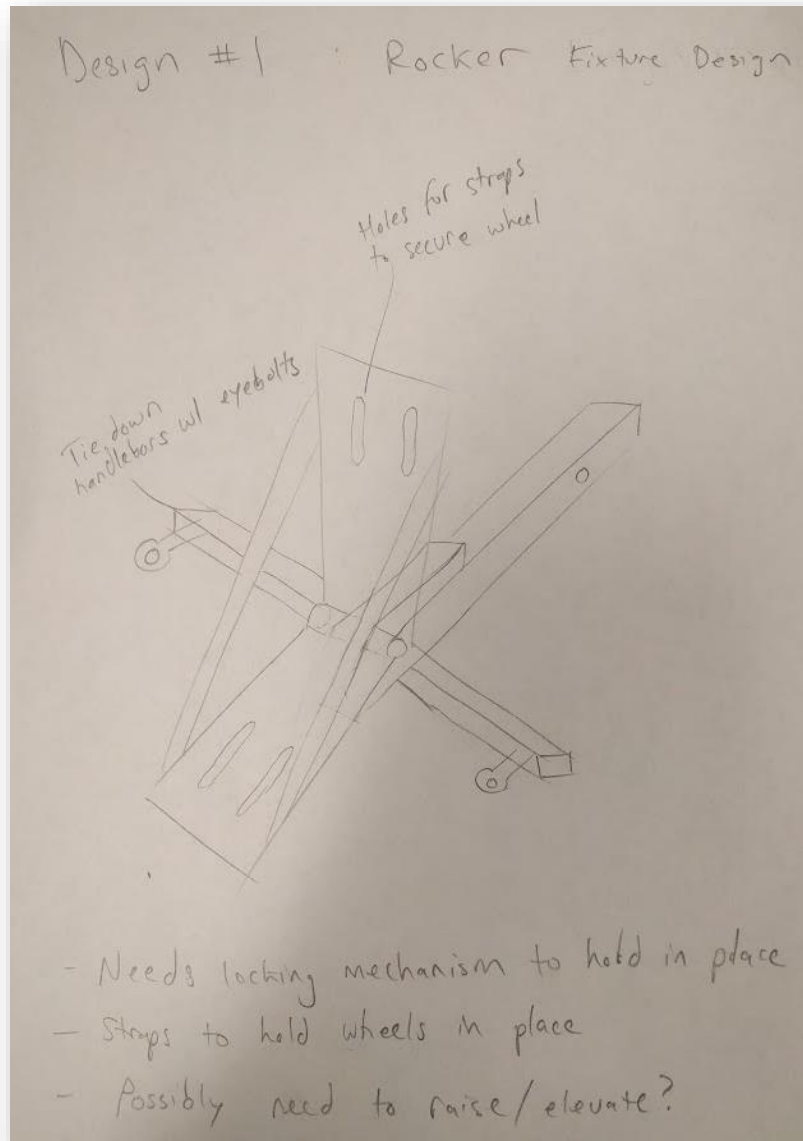
**CONCEPT DESIGN*****CONCEPT DESIGN #1 – ROCKER FIXTURE DESIGN***

Figure 4 – Design 1: Rocker Fixture Design

This design will feature a rocker type fixture, similar to one in the researched product “The Original Slick Wheelie Motorcycle Hauler”. However, it will use more common square tubing as the base and a rocker that will use the power of the motorcycle in order to lift up front wheel of the motorcycle onto the hitch. It will feature a longer base to allow the rocker to drive up on to the fixture. It also features tie down eyebolts to allow the handlebars to be secure, preventing the motorcycle from leaning or tipping over during transport.

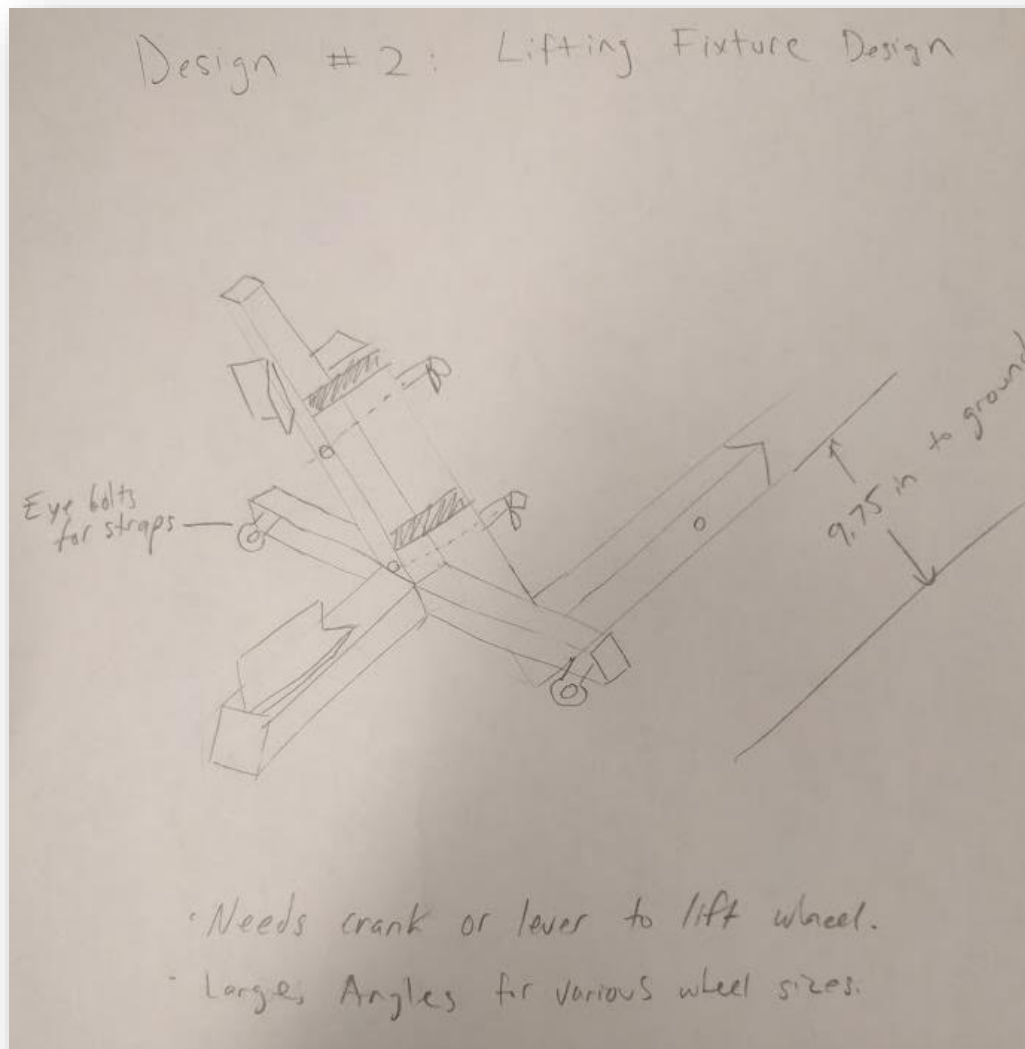
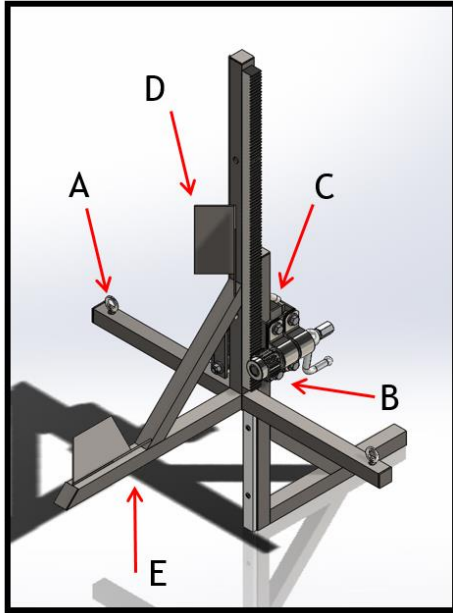
**CONCEPT DESIGN #2 – LIFTING FIXTURE DESIGN**

Figure 5 – Design 2: Lifting Fixture Design

This design would allow the user to push the front tire on the fixture while it is in its lowered position, then simply crank up the L bracket to its raised position using a gearing mechanism such as a rack and pinion. This design also has eyebolts for handlebar tie down as well as pins for securing the bracket in both the lowered and raised positions.

## DESIGN SELECTION

### *DRAWINGS*



- A. Eyebolts for handlebar tie down
- B. Rack and pinion for lifting capability
- C. Standard hitch bolts for locking into position
- D. Large tire holding angles for a variety of tire sizes
- E. Higher ground clearance for low riding vehicles

Figure 6 – Lifting Fixture Design

### *LOADING CONDITIONS*

The loading conditions of the fixture are to be determined in both the lowered and raised position. In the lowered position the bracket will be lowered on to the ground, thus it is only important to calculate the cross sectional stress in the angle and tube below it. On the other hand, the stress of the weldments is to be analyzed when it is in the raised position, and many stresses to be calculated.

- Safety factor of 3 to 5 (manufacturer's)
  - Trailer hitch tongue weight – 200 lbs. maximum
- Minimum safety factor of 2
  - Structural Members
- Minimum safety factor of 5
  - Rack and Pinion Design
  - Shaft and Bearing Design
  - Roller Bearing Bracket Design
  - Pin Design

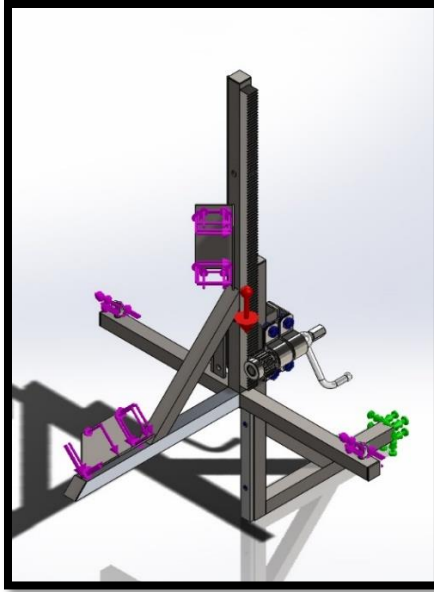


Figure 7 - Loading Conditions for Main Assembly

As depicted in Figure 7, the main loading conditions are the force of the front end of the motorcycle resting on the two angles, the tensile force of the ratchet straps on the eyebolts at the ends, the weight of the fixture itself, and the fixed location where it attaches to the car hitch receiver.

DESIGN ANALYSIS

Structural Analysis

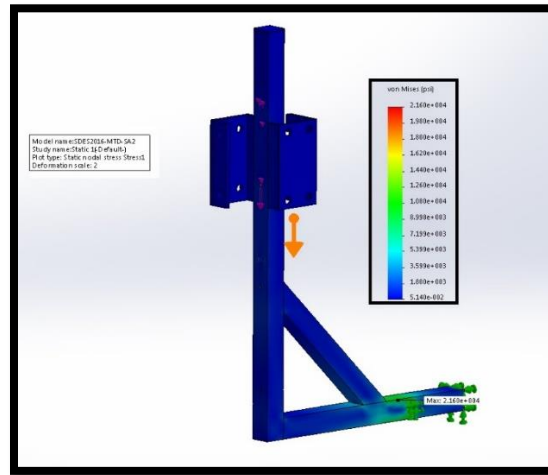


Figure 8 - Static Strain (vonMises)  
 Maximum: 21,600 psi  
 Material Yield Strength:  
 47,137 psi (1015 Steel)  
 (deformation scale: 2)

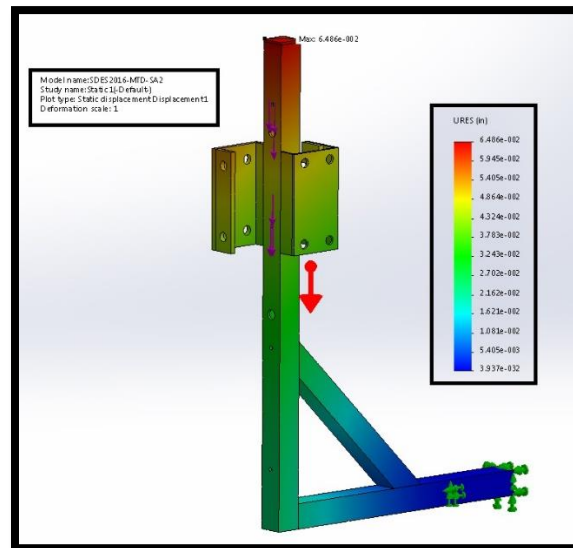


Figure 9 – Displacement  
 Maximum: 0.06 in  
 (deformation scale: 2)

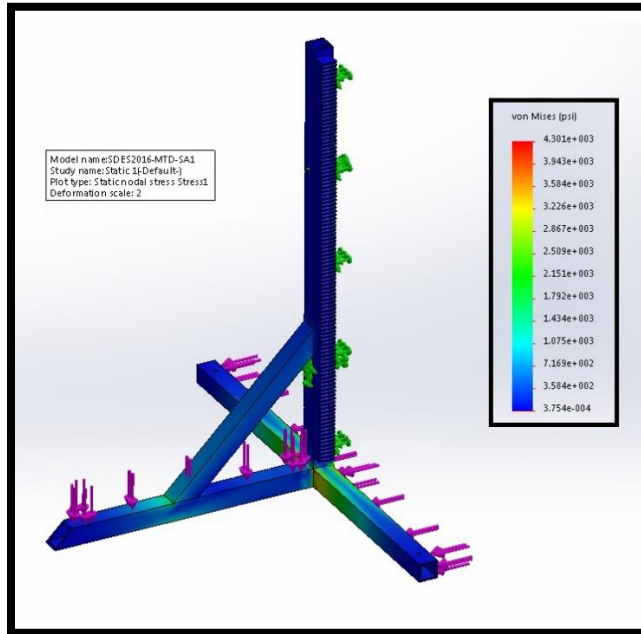


Figure 10 - Static Strain (vonMises)  
Maximum: 4,301 psi  
Material Yield Strength:  
43,137 psi (1015 Steel)  
(deformation scale: 2)

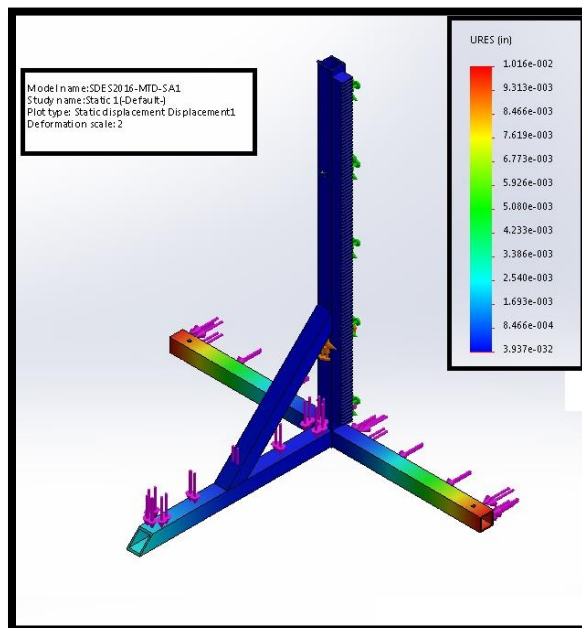


Figure 11 - Displacement  
Maximum: 0.01 in  
(deformation scale: 2)

The above figures show the static strain when the weldment is holding the motorcycle in the raised position. Both weldments were assessed individually as they are separate components of the system. Both strain and displacement were calculated in order to bring to light any possible structural problems.

**Pin Analysis**

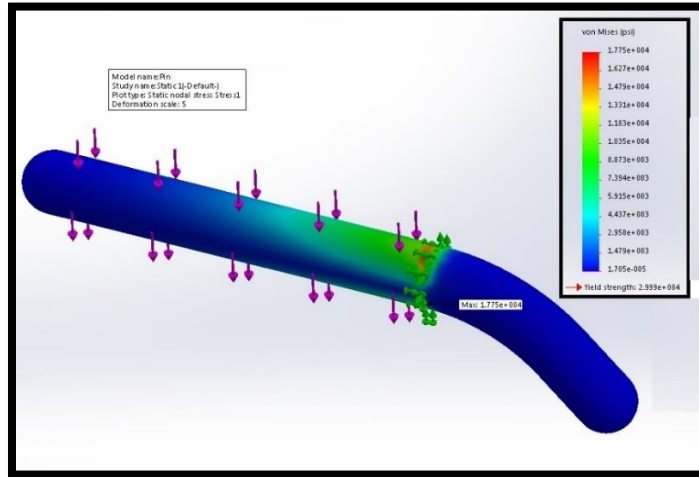


Figure 12 – Shear Strain (vonMises)  
 Maximum: 17,750 psi  
 Material Yield Strength:  
 29,990 psi (SS)  
 (deformation scale: 5)

**Rack and Pinion Analysis**

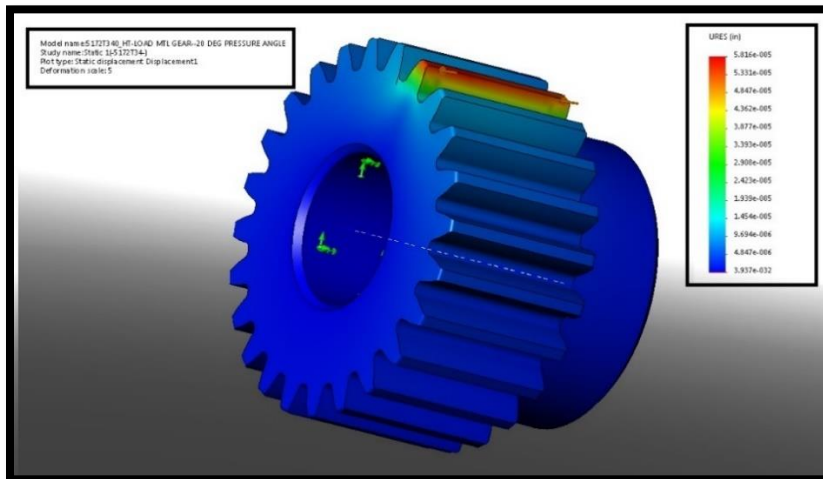


Figure 13 – Tooth Bending Strain (vonMises)  
 Maximum: 58,160 psi  
 Material Yield Strength:  
 60,200 psi (303 SS)  
 (deformation scale: 5)

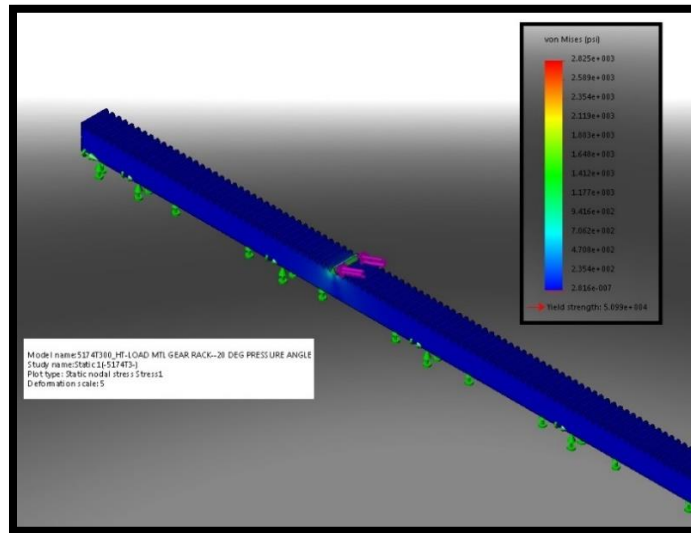


Figure 14 – Tooth Bending Strain (vonMises)  
 Maximum: 2,325 psi  
 Material Yield Strength:  
 50,990 psi (SS)  
 (deformation scale: 5)

The rack and pinion gearing teeth were checked to ensure the bending force on the teeth was not greater than the yield strength of the material, with a safety factor of 5.

**Roller Bearing Bracket Analysis**

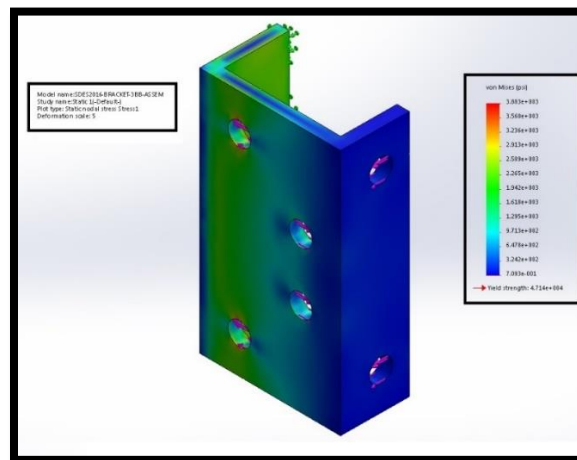


Figure 15 - Bending Strain (vonMises)  
 Maximum: 3,883 psi  
 Material Yield Strength:  
 47,140 psi (1018 SS)  
 (deformation scale: 5)

The roller bearings that were used to allow the fixture to traverse up and down was analyzed for bending stresses accounting for strain on each roller bearing from the designed weight.

### Shaft Analysis

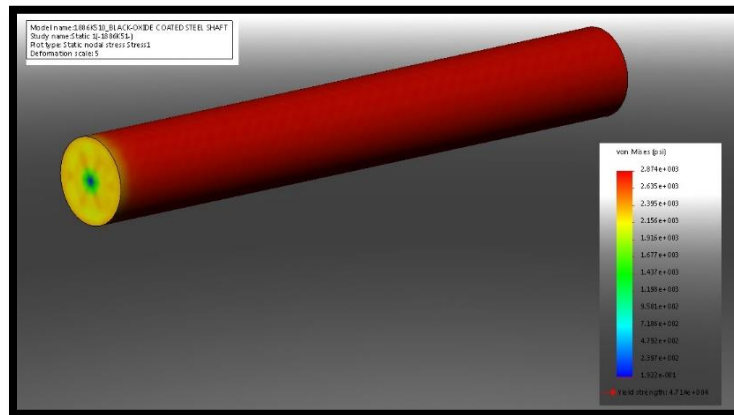


Figure 16 - Torsional Strain (vonMises)  
Maximum: 2,874 psi  
Material Yield Strength:  
40,714 psi (303 SS)  
(deformation scale: 5)

***COMPONENT SELECTIONS***

Most of the component selections were based off the premise of saving weight. After stress analysis was completed, most of the weight calculations were the deciding factor in terms of component selection. Although steel would be an optimal material for this design, to save on weight 6061-T6 aluminum, which can be seen in the table below. However, based on the stress analysis for the shaft assembly, the only option was to use materials that were able to withstand the forces that came while raising the motorcycle. In this case, the only option was to use steel or stainless steel components. Note: The weight of standard part is to be determined and is not accounted for in these preliminary calculations for part selection. See Appendix for complete table of weights.

Table 3 – Calculated Design Weights

<b>Design</b>	<b>Type</b>	<b>Calculated Weight (lbs)</b>	<b>Difference (lbs)</b>
Design 1	F1+RP1+C1+SH1+H	20.71	20.92
Design 2	F1+RP2+C1+SH1+H	13.80	27.82
Design 3	F1+RP1+C1+SH2+H	20.71	20.92
Design 5	F2+RP2+C1+SH1+H	25.38	16.25
<b>Design 6</b>	<b>F2+RP1+C1+SH1+H</b>	<b>39.51</b>	<b>2.12</b>
<b>Design Weight (lbs)</b>			
41.62			

## **TESTING**

### ***TESTING METHODS***

#### *Methods*

- Measurement of the weight of fixture
- Setup and teardown time
  - Including lifting capability
- Test Drive
  - Off street testing
    - Forward
    - Reverse
    - Turns
    - Road bumps

### ***RESULTS AND PROOF OF DESIGN***

#### *Results*

- Total weight: 43.4 lbs.
  - Car weldment: 17.6 lbs.
  - Motorcycle weldment: 25.8 lbs.
- Setup time
  - 15 minutes
  - Rack and pinion lifts motorcycle as intended
- Test Drive
  - Holds designed weight under stress
  - Leans excessively

#### *Moving Forward*

- Possible design changes for production
  - Ratcheting mechanism for crank
  - Remove eyebolt tie down locations
    - Design and include fork lock
  - Add additional hitch pin holes for varying fixture heights
  - Convert to commercial linear rail guide
  - Machined or bent brackets



Table 5 – Actual Budget

Design Type	Assembly	Standard Part Name	Vendor Item Number	Price Per Unit	Quantity	Description	Vendor	Total Price
H1	SA3	SHAFT	1886K510	11.82	1	BLACK OXIDE COATED STEEL SHAFT	McMaster Carr	11.82
H1	A	ROLLER	3643K800	39.33	6	HT-LOAD THREDED TRACK ROLLER	McMaster Carr	235.98
H1	SA3	PINION	5172J340	40.98	1	HT-LOAD MTR GEAR, 20°	McMaster Carr	40.98
H1	SA2	RACK	5174T13	63.14	1	HT-LOAD MTR GEAR RACK, 20° 4FT.	McMaster Carr	63.14
H1	SA3	CRANK	6336K7	53.77	1	STEEL CRANK HANDLE	McMaster Carr	53.77
H1	SA3	BEARING	7930K160	25.92	2	VIBRATION DAMPING SLEEVE BRNG	McMaster Carr	51.84
H1	SA2	EYEBOLT	8891T720	11.28	2	1/4-20 316 SSTHREAD EYEBOLT	McMaster Carr	22.56
H1	A	LOCKNUT	91831A135	7.94	1	7/16-20 SS NYLON LOCKNUT (25)	McMaster Carr	7.94
H1	A	SCREW	92240A401	5.99	1	7/16-20 SS HEX HEAD SCREW 1" LG (10)	McMaster Carr	5.99
H1	A	LOCKNUT	91831A029	4.42	1	1/4-20 SS NYLON LOCKNUT (25)	McMaster Carr	4.42
H1	A	HITCH PIN	94563A811	7.93	2	1/2" HITCH PIN	McMaster Carr	15.86
H1	A	WASHER	98370A022	9.76	1	7/16 SS OVERSIZED WASHER (10)	McMaster Carr	9.76
H1	A	SCREW	92196A540	9.53	1	1/4-20 SS SOCKET HEAD SCREW (50)	McMaster Carr	9.53
	A	.125" SHT	8975K921	12.78	1	2 FT. STEEL UNPOLISHED SHEET	McMaster Carr	12.78
	A	.250" SHT	8975K437	13.37	1	1 FT. STEEL UNPOLISHED SHEET	McMaster Carr	13.37
	A	.375" SHT	8739K26	9.72	1	2 FT. WHITE DELRIN BAR	McMaster Carr	9.72
	SA1 + SA2	TUBING	3DRR6	29.1	3	1.25" X 1.25" X .125" THK STEEL TUBING	Granger	87.3
	SA1	ANGLE	8982K4	14.06	1	1" X 1" X .25" THK X 36" LG ANGLE	McMaster Carr	14.06
	SA1	ANGLE	9017K734	8.96	1	3" X 3" X .125" THK X 12" LG ANGLE	McMaster Carr	8.96
							<b>Total</b>	<b>\$ 679.78</b>

Comparing the initial to the actual budget, you can see there was the change of material from 6061 T6 Aluminum to the steel structural members: tubing, angles, plate stock, bolts etc. There was also a change from a more expensive crank to a cheaper one that was modified to fit the shaft.

SCHEDULE

Motorcycle Tow Dolly - Senior Design

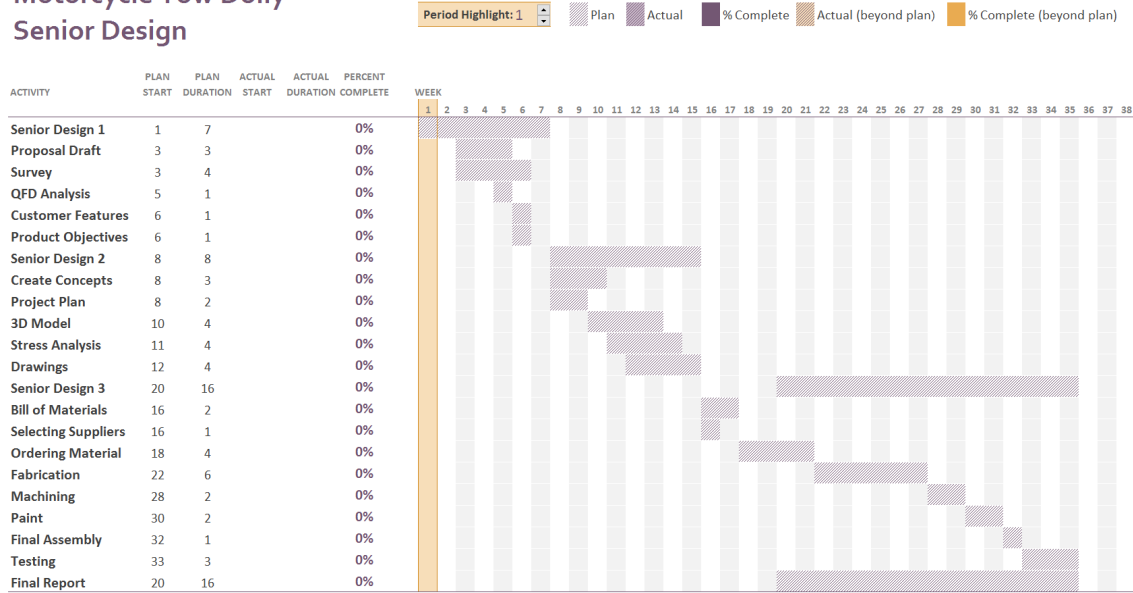


Figure 17 – Initial Schedule

This schedule shows the main points that will take place during the three Senior Design courses. It includes important dates and updated weekly during the design process in order to meet all the key dates. This above schedule only shows the planned dates, the below schedule shows the planned start and end dates in comparison to the actual start and end dates in this same easy to view format.

Motorcycle Tow Dolly - Senior Design

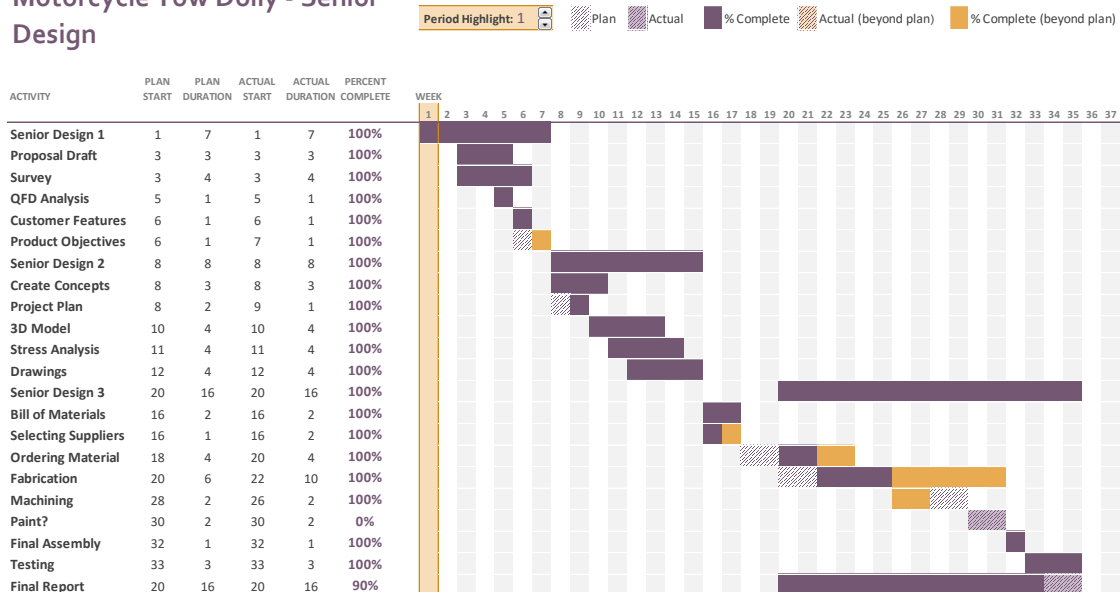


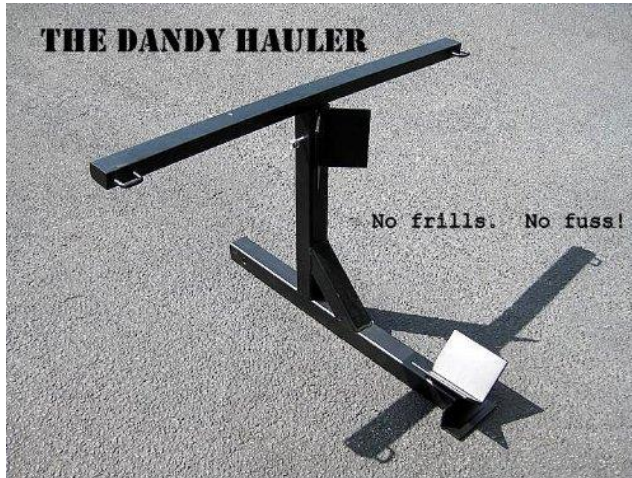
Figure 18 – Actual Schedule

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## APPENDIX A – RESEARCH

### Dandy Hauler – A Motorcycle Carrier (3)



The USA Trailer Store's got you covered! We've added yet another budget-friendly product to our line of high quality, low cost transportation delights that will allow you to have fun with family and friends and still have money in your pockets.

Here's what you do:

1. Simply attach the Dandy Hauler to any 2" Class II or Class III receiver\*.
2. Using a ramp or 2"x6" piece of lumber, roll your motorcycle onto the Dandy Hauler's v-shaped tire cradles, strap it down, and go! Go wherever you like - Daytona, Myrtle, Moab..

### Specifications:

- Construction: 1/4" Powder-Coated Steel
- Weight: 26lbs with tie-down bar (21lbs without)
- Hauler Dimensions: 30"(L) x 2"(W) x 20"(H)
- Tie-Down Bar Dimensions: 36"(L) X 2"(W) x 1"(H)
- Accommodates tires sized: All Sizes

### Price:

- **\$109.00 or \$89.00 plus shipping**

This product has the design for durability and reliability. This simplistic tow dolly includes a couple features that can be used in a new design such as the tie down straps, however they may be better off in line with the front forks of the motorcycle in order to provide increased stability.

The Original Slick Wheelie Motorcycle Hauler (7)



The Slick Wheelie attaches in seconds to a 2" Class II or Class III receiver, and it's all steel construction allows for this unit to haul bikes with a curb weight of up to 1000 lbs. Other transports require you to struggle with pushing your bike up a ramp. Not this baby!

It's as easy as...

1. Simply turn the crank and the cradle lowers to ground level
2. Insert and secure the front wheel. Then,
3. Turn the crank in the opposite direction to raise the bike to the transport position.

**Specifications:**

- Specifications
- Includes 2 - 2" ratcheting straps with hooks.
- Assembles and installs in minutes.
- The entire unit weighs a very manageable 32 lbs. and measures 40"x8"x9"
- You can store it in your trunk or behind your seat in your car!
- Note-This unit will not accommodate bike tires greater than 5 1/2" wide

**Price:**

- **\$144.95 plus shipping**

The Slick Wheelie has a great concept on how to raise the front tire up, allowing anyone to simply roll the tire into the fixture without the use of ramps. This can be incorporated into the design project, perhaps in a different way. Unfortunately, it does not raise up above the motorcycle hitch height, which is needed for this design project as Class I hitch vehicles are often lower to the ground than Class II or Class III hitch vehicles.

TMS Motorcycle Trailer Hitch Carrier (5)



Accommodates most motorcycle wheel diameters and widths. This type of trailer is for manual transmission motorcycles and scooters. Saves on gas and requires minimal storage space. Designed to pull your motorcycle without the use of a trailer.

Adjustable height allows you to raise and lower the cradle with a crank.

**Specifications:**

- 16" X 14.5" X 7.8"
- 30 pounds
- Attaches to any 2" Class II or Class II hitch Receiver
- Maximum Weight Capacity of 800 lbs

**Price:**

- **\$110.06**

This design has a lever lifting mechanism which is noticeably different than The Original Slick Wheelie, mentioned above. It can also be folded up into a smaller profile which can be a feature to consider in the design.

## Material Selections

Design Type	Assembly	Part	Material	Yield Strength (psi)	Tensile Strength (psi)	Weight/ft.	Size (in)	Total Length (ft)	Vendor	Total Weight (lb)
F1	SA1	Tubing	6061 T6	45000	40000	0.68	0.125	6.90	McMaster Carr	4.69
F1	SA1	Angle	6061 T6	45000	40000	1.68	0.25	1.00	McMaster Carr	1.68
F1	SA2	Tubing	6061 T6	45000	40000	0.68	0.125	4.63	McMaster Carr	3.15
F1	SA2	Angle	6061 T6	45000	40000	0.27	0.125	2.29	McMaster Carr	0.62
									<b>Total</b>	<b>9.52</b>
F2	SA1	Tubing	1015	34000	85000	1.5	0.062	6.90	McMaster Carr	10.34
F2	SA1	Angle	1015	34000	85000	3.8	0.1875	1.00	McMaster Carr	3.80
F2	SA2	Tubing	1015	34000	85000	1.5	0.062	4.63	McMaster Carr	6.95
F2	SA2	Angle	1015	34000	85000	0.8	0.125	2.29	McMaster Carr	1.83
									<b>Total</b>	<b>21.09</b>
F3	SA1	Tubing	304 SS	34000	85000	1.92	0.12	6.90	McMaster Carr	13.24
F3	SA1	Angle	304 SS	34000	85000	4.9	0.25	1.00	McMaster Carr	4.90
F3	SA2	Tubing	304 SS	34000	85000	1.92	0.12	4.63	McMaster Carr	8.89
F3	SA2	Angle	304 SS	34000	85000	0.8	0.125	2.29	McMaster Carr	1.83
									<b>Total</b>	<b>27.03</b>
RP1	SA3	Rack	SS	34000	85000	3.4	1x1	2.33	McMaster Carr	7.93
RP1	SA3	Pinion	SS	34000	85000	2.95	1	1.62	McMaster Carr	1.62
									<b>Total</b>	<b>9.55</b>
RP2	SA3	Rack	Plastic	Unknown	Unknown	1.1032	1x1	2.33	McMaster Carr	2.57
RP2	SA3	Pinion	Plastic	Unknown	Unknown	0.0324	1	2.33	McMaster Carr	0.08
									<b>Total</b>	<b>2.65</b>
SH1	SA3	Shaft	Steel	Unknown	Unknown	2.05	0.875	0.67	McMaster Carr	1.37
SH2	SA3	Shaft	Aluminum	Unknown	Unknown	0.71	0.875	0.67	McMaster Carr	0.47
P1	ALL	Sheet	6061 T6	Unknown	Unknown	1.8	0.125	1	McMaster Carr	1.80
P1	ALL	Sheet	6061 T6	Unknown	Unknown	3.52	0.25	0.5	McMaster Carr	1.76
C1	SA1 + SA2	Sheet	6061 T6	45000	40000	0.09	0.0625	3	McMaster Carr	0.27

<b>Design</b>	<b>Type</b>	<b>Calculated Weight (lbs)</b>	<b>Difference (lbs)</b>
Design 1	F1+RP1+C1+SH1+H	20.71	20.92
Design 2	F1+RP2+C1+SH1+H	13.80	27.82
Design 3	F1+RP1+C1+SH2+H	20.71	20.92
Design 5	F2+RP2+C1+SH1+H	25.38	16.25
Design 6	F2+RP1+C1+SH1+H	39.51	2.12
<b>Design Weight (lbs)</b>			
		41.62	

# APPENDIX B - SURVEY WITH RESULTS

## SURVEY

**Methods of Transporting a Motorcycle Survey**

\*\* PLEASE READ \*\*

This survey will be used to prioritize specific features in order to maximize customer satisfaction. It will be addressing common issues when transporting a motorcycle/scooter/dirt bike using a trailer/dolly. This survey is completely anonymous and will be used for research purposes only.

\* 1. Overall, how important is each feature to you regarding transporting a motorcycle?

	Very Unimportant	Somewhat Unimportant	Neutral	Somewhat Important	Very Important	N/A
Reliability	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Durability	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Storage (Size and Weight)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Motorcycle Security	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Lifetime of Product	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Price	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Functionality	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Setup Time	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Carrying Capacity	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Corrosive Resistance	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

\* 2. Overall, how satisfied are you with current methods for transporting motorcycles/scooters?

	Very Unsatisfied	Somewhat Unsatisfied	Neutral	Somewhat Satisfied	Very Satisfied	N/A
Reliability	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Durability	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Storage (Size and Weight)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Motorcycle Security	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Lifetime of Product	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Price	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Functionality	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Setup Time	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Carrying Capacity	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Corrosive Resistance	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

\* 3. How much would you be willing to invest in this technology?

- < \$100
- \$100 - \$250
- \$250 - \$500
- \$500 - \$1000
- \$1000 - \$2500
- > \$2500

Done

(8).

**RESULTS**

**Overall, how important is each feature to you regarding transporting a motorcycle?**

Answered: 9 Skipped: 0

	Very Unimportant	Somewhat Unimportant	Neutral	Somewhat Important	Very Important	N/A	Total	Weighted Average
Reliability	0.00% 0	11.11% 1	11.11% 1	22.22% 2	55.56% 5	0.00% 0	9	4.22
Durability	0.00% 0	0.00% 0	11.11% 1	44.44% 4	44.44% 4	0.00% 0	9	4.33
Storage (Size and Weight)	0.00% 0	22.22% 2	33.33% 3	33.33% 3	11.11% 1	0.00% 0	9	3.33
Motorcycle Security	0.00% 0	0.00% 0	0.00% 0	22.22% 2	66.67% 6	11.11% 1	9	4.75
Lifetime of Product	0.00% 0	11.11% 1	22.22% 2	33.33% 3	33.33% 3	0.00% 0	9	3.89
Price	0.00% 0	0.00% 0	33.33% 3	22.22% 2	44.44% 4	0.00% 0	9	4.11
Functionality	0.00% 0	0.00% 0	11.11% 1	22.22% 2	66.67% 6	0.00% 0	9	4.56
Setup Time	11.11% 1	0.00% 0	11.11% 1	33.33% 3	44.44% 4	0.00% 0	9	4.00
Carrying Capacity	11.11% 1	33.33% 3	0.00% 0	22.22% 2	33.33% 3	0.00% 0	9	3.33
Corrosive Resistance	0.00% 0	11.11% 1	22.22% 2	33.33% 3	33.33% 3	0.00% 0	9	3.89

**Overall, how satisfied are you with current methods for transporting motorcycles/scooters?**

Answered: 9 Skipped: 0

	Very Unsatisfied	Somewhat Unsatisfied	Neutral	Somewhat Satisfied	Very Satisfied	N/A	Total	Weighted Average
Reliability	11.11% 1	11.11% 1	22.22% 2	22.22% 2	22.22% 2	11.11% 1	9	3.38
Durability	11.11% 1	22.22% 2	11.11% 1	44.44% 4	0.00% 0	11.11% 1	9	3.00
Storage (Size and Weight)	11.11% 1	44.44% 4	11.11% 1	11.11% 1	11.11% 1	11.11% 1	9	2.63
Motorcycle Security	0.00% 0	11.11% 1	11.11% 1	55.56% 5	0.00% 0	22.22% 2	9	3.57
Lifetime of Product	0.00% 0	0.00% 0	44.44% 4	44.44% 4	0.00% 0	11.11% 1	9	3.50
Price	0.00% 0	22.22% 2	22.22% 2	33.33% 3	11.11% 1	11.11% 1	9	3.38
Functionality	0.00% 0	11.11% 1	11.11% 1	55.56% 5	11.11% 1	11.11% 1	9	3.75
Setup Time	0.00% 0	0.00% 0	22.22% 2	55.56% 5	11.11% 1	11.11% 1	9	3.88
Carrying Capacity	0.00% 0	11.11% 1	33.33% 3	33.33% 3	0.00% 0	22.22% 2	9	3.29
Corrosive Resistance	0.00% 0	22.22% 2	33.33% 3	33.33% 3	0.00% 0	11.11% 1	9	3.13

**How much would you be willing to invest in this technology?**

Answered: 9 Skipped: 0

Answer Choices	Responses
< \$100	11.11% 1
\$100 - \$250	22.22% 2
\$250 - \$500	22.22% 2
\$500 - \$1000	22.22% 2
\$1000 - \$2500	22.22% 2
> \$2500	0.00% 0
Total	9

(8)

# APPENDIX C - QUALITY FUNCTION DEPLOYMENT (QFD)

## QUALITY FUNCTION DEPLOYMENT MATRIX

Note: \*\*Shown in Interaction Matrix\*\*

		Engineering Requirements (units)														Customer Satisfaction Rating (0.00 - 1.00)			
		Importance wt.	Number of Features (#)	Maximum Impact Strength in Structural Members (lbf)	Number of Uses before failure (#)	Lifting Cycles (#)	Maximum Shear Force on Pin (lbs)	Material Cost (\$)	Setup Time (hrs)	Life Under Load (# of hrs)	Painted (Yes/No)	Maximum Load on Fixture (lbs)	Weight of Fixture (lbs)	Length (in)					
Customer Requirements		1	2	3	4	5	6	7	8	9	10	11	12	13	14	CP	A	B	C
1	Functionality	0.1142	10	3	1			1				3							
2	Durability	0.1086		10	3	3	3	1		3		9	1						
3	Reliability	0.1058		3	3	10	3			9		3							
4	Motorcycle Security	0.1058	3	3			10			3		3	1						
5	Price	0.1031		1				3			3	3	1	1					
6	Setup Time	0.1003	3						10				3	1					
7	Lifetime of Product	0.9750		3	9	3	3			10		3							
8	Corrosive Resistance	0.9750						3			10								
9	Carrying Capacity	0.8360					9			3		10	3						
10	Storage (Size and Weight)	0.8360	1										9	10					
Total Importance		1.00																	
Engineering requirement importance			2.6	5.1	9.5	4.3	12.2	3.3	1.1	13.9	10.1	13.5	10.7	8.6					

Legend:

Correlation	Value
Strongest	10
Strongest	7
Fair	3
Weak	1

## INTERACTION MATRIX

Interaction Matrix															
	Engineering Requirements	Number of Features (#)	Maximum Impact Strength in Structural Members (lbf)	Number of Uses before failure (#)	Lifting Cycles (#)	Maximum Shear Force on Pin (lbs)	Material Cost (\$)	Setup Time (hrs)	Life Under Load (# of hrs)	Painted (Yes/No)	Maximum Load on Fixture (lbs)	Weight of Fixture (lbs)	Length (in)		
Engineering Requirements		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Number of Features (#)	1						+	+							
Maximum Impact Strength in Structural Members (lbf)	2					⊕			⊕						
Number of Uses before failure (#)	3						+				⊖				
Lifting Cycles (#)	4								-		-				
Maximum Shear Force on Pin (lbs)	5										⊕				
Material Cost (\$)	6									+		+			
Setup Time (hrs)	7										+	+	+		
Life Under Load (# of hrs)	8										⊕	+			
Painted (Yes/No)	9														
Maximum Load on Fixture (lbs)	10											+			
Weight of Fixture (lbs)	11												+		
Length (in)	12														
	0	13													
	0	14													

Legend:

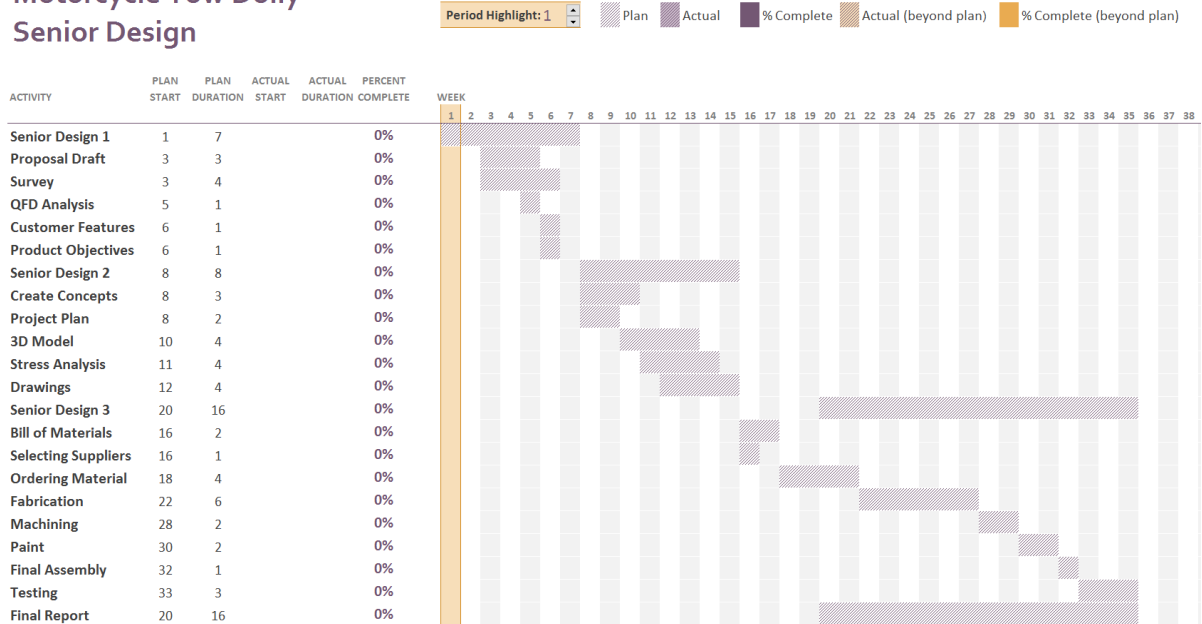
Correlation	Value
Strong Positive	⊕
Positive	+
Strong Negative	⊖
Negative	-

## APPENDIX D - OBJECTIVES

- **Functionality**
  - Number of designed features that are used by the customer in order to aid in the use of a product such as tie down locations for handlebars.
- **Durability**
  - The enduring qualities of a product. Designed to resist wear and tear from possible road debris.
- **Reliability**
  - The ability for the product to perform as it is intended by meeting customer and design specifications time after time. Intended to be used when transporting a motorcycle long distances.
- **Motorcycle Security**
  - Added safety features and stability when operating provide increased safety for the product, such as tie down straps or locking mechanisms.
- **Price**
  - Costs for material and manufacturing labor directly reduce the cost that can be forwarded to the customer such as designing using standard material sizes.
- **Storage (Size and Weight)**
  - Possible to disassemble the product into a smaller footprint than the size of the product in its usable state.
  - Lightweight in order to allow easy storage and setup, under 45 lbs.
- **Setup Time**
  - Short amount of time to remove from the product storage and setup the product into a usable state. Be able to raise or lower motorcycle quickly.
- **Corrosive Resistance**
  - Protected against weather elements that may damage the equipment or product over a long period of time by painting or protecting equipment.
- **Lifetime of Product**
  - Built for a designed number of hours, with the expected number of uses in mind. Expected to last at least 10 years.

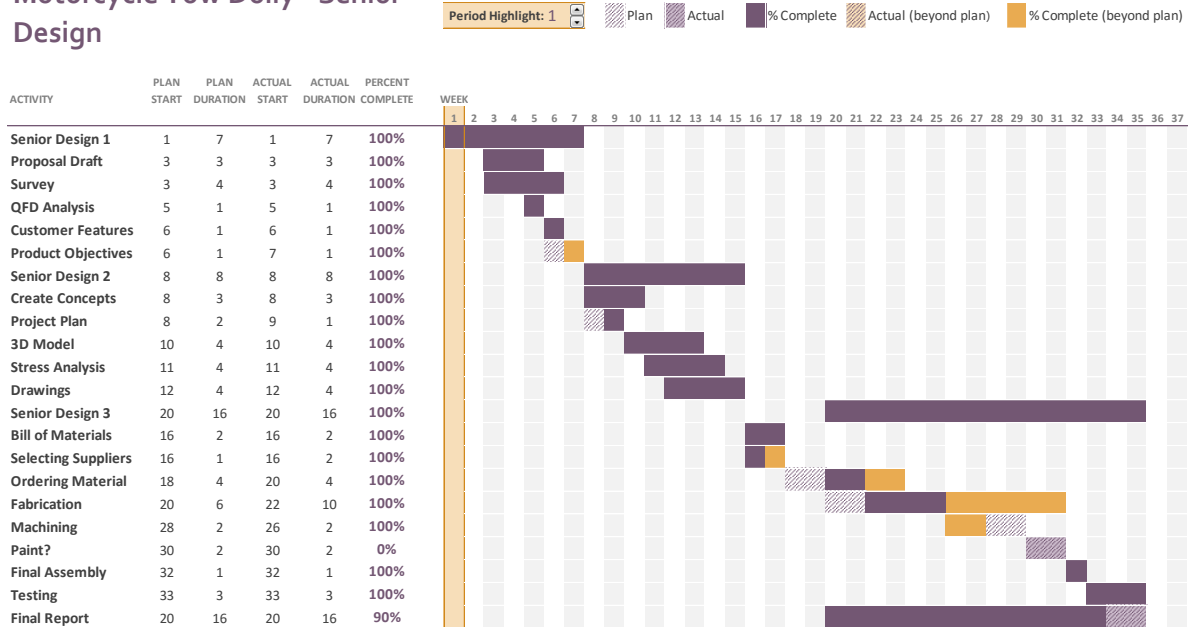
# APPENDIX E - SCHEDULE

## Motorcycle Tow Dolly - Senior Design



Preliminary Schedule

## Motorcycle Tow Dolly - Senior Design



Actual Schedule





## APPENDIX G – PROOF OF DESIGN

- **Functionality**
  - Tie down bar with eyebolts with straps for securing the handlebars
  - Rack and Pinion mechanism for easing raising and lowering the front wheel
  - Easy to install and remove pin for both positions.
- **Durability**
  - Product will be coated with flexible coating on underside of fixture
  - Made with hardened aluminum to save on weight
- **Reliability**
  - Stainless steel rack and pinion
  - Bearing life to exceed 5000 hours.
- **Motorcycle Security**
  - Tie down bar for safety
  - Added wheel straps for increased security
- **Price**
  - Use of standard parts as well as cheaper aluminum for cost savings.
- **Storage (Size and Weight)**
  - Possible to disassemble the product into a smaller footprint than the size of the product in its usable state.
  - Lightweight to allow easy storage and setup, under 45 lbs.
- **Setup Time**
  - A setup time of under 30 minutes.
- **Corrosive Resistance**
  - Any bare corrosion-prone metal to be painted.
- **Lifetime of Product**
  - Built for a designed number of hours, with the expected number of uses in mind. Expected to last at least 10 years.

## APPENDIX H – CALCULATIONS

### MOTORCYCLE CENTER OF GRAVITY (9)

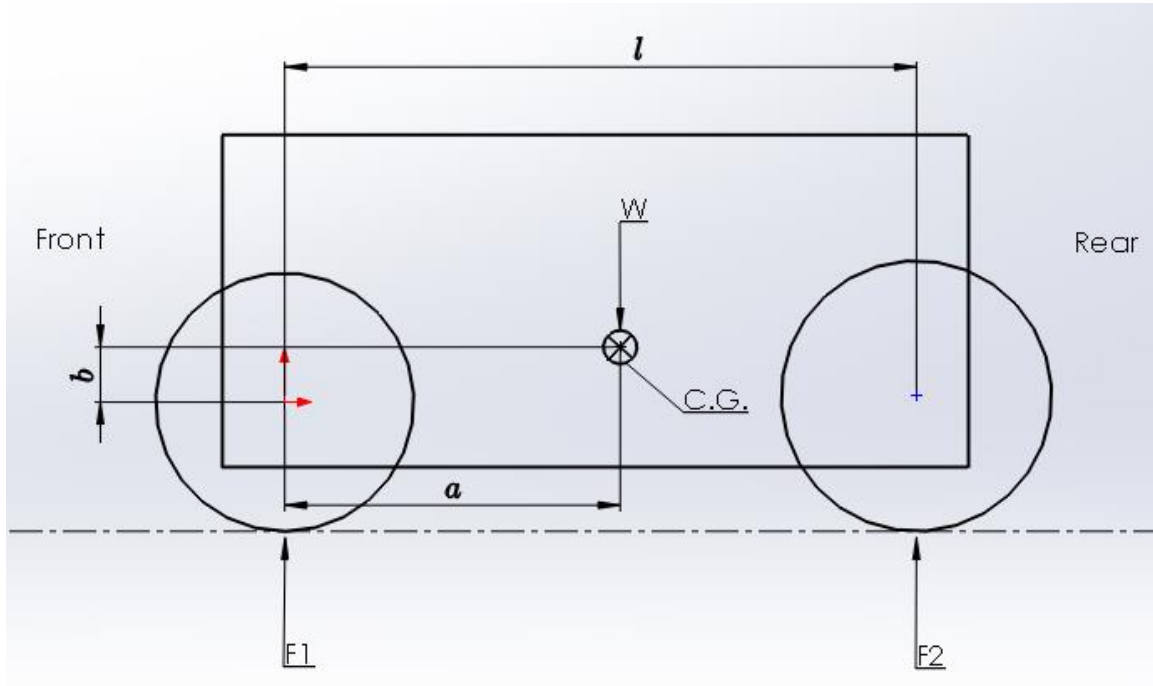


Figure 19 – Forces on Motorcycle on Level Ground

Table 6 – Ninja 500 Specifications

Ninja 500 Specifications	
Wheelbase, $l$ (in):	56.5

Table 7 – Level Ground Measured Values

Measured Values	
Front Wheel Weight, $F_1$ (lbs)	197
Rear Wheel Weight, $F_2$ (lbs)	223

$$(+\uparrow)\Sigma F_y = F_1 + F_2 - W = 0$$

$$197 \text{ lbs} + 223 \text{ lbs} - W = 0$$

$$\text{Total Motorcycle Weight, } W = 420 \text{ lbs}$$

$$(+\odot)\Sigma M_{F_1} = F_2 * l - W * a = 0$$

$$223 \text{ lbs} * 56.5 \text{ in} - 420 \text{ lbs} * a = 0$$

$$\text{Center of Gravity horizontal distance, } a = 30.0 \text{ in}$$

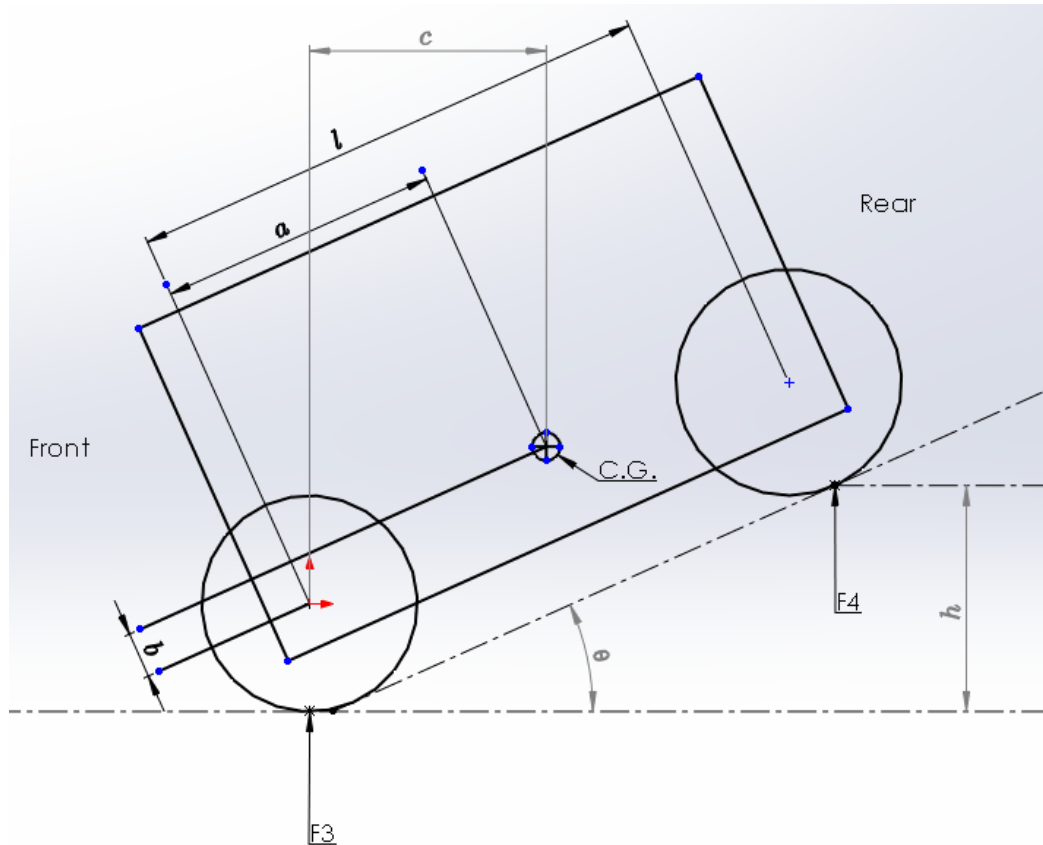


Figure 20 – Forces on a Motorcycle on an Incline

Table 8 – Ninja 500 Specifications (cont'd)

<b>Ninja 500 Specifications</b>	
Wheelbase, $l$ (in):	56.5
Dry weight, $W_{dry}$ (lbs):	388
Wet weight, $W_{wet}$ (lbs):	438
Weight with 1 gal gas, $W_{1g}$ (lbs):	412.03
Front tire dia (in)	23.1
Rear tire dia (in)	24.2
Engine oil volume (qts)	3.59
Tank gas storage (gal)	4.2

Table 9 – Inclined Measured Values

Measured Values	
Front Wheel Weight, F1 (lbs)	197
Rear Wheel Weight, F2 (lbs)	223
Weight, W (lbs)	420
Battery weight, Wb (lbs)	10.2
Coolant weight, Wc (lbs)	6.65
Engine oil weight, We (lbs)	7.18
Height lifted off the ground, h (in)	9
Weight at back tire, F4 (lb)	218

**Weight with 1 gal gas,  $W1g(lbs) = W_{dry} + W_b + W_c + W_e$**

$$W1g(lbs) = 388 lbs + 10.2 lbs + 6.65 lbs + 7.18 lbs$$

$$W1g = 412.03 lbs$$

$$\text{Angle of Inclination, } \theta (^{\circ}) = \tan^{-1} \left( \frac{\text{opp}}{\text{adj}} \right)$$

$$\theta (^{\circ}) = \tan^{-1} \left( \frac{9 \text{ in}}{56.5 \text{ in}} \right)$$

$$\theta = 9.05^{\circ}$$

$$\text{Angle of Inclination, } \theta(\text{rad}) = \frac{\pi}{180} * 9.05^{\circ}$$

$$\theta = 0.158 \text{ rad}$$

$$(+\cup)\Sigma M_{F_3} = F_4 * l * \cos\theta - W * c = 0$$

$$\& c = a * \cos\theta - b * \sin\theta, \text{ solving for } b$$

$$b = \frac{(W * a - F_4 * l)\cos\theta}{W * \sin\theta}$$

$$b = \frac{(420 \text{ lbs} * 30.0 \text{ in} - 216 \text{ lbs} * 56.5 \text{ in})\cos(9.05^{\circ})}{420 \text{ lb} * \sin(9.05^{\circ})}$$

Center of Gravity vertical distance,  $b = 8.29 \text{ in}$

$$c = a * \cos\theta - b * \sin\theta$$

$$c = 30.0 \text{ in} * \cos(9.05^{\circ}) - 8.29 \text{ in} * \sin(9.05^{\circ})$$

$$c = 28.32 \text{ in}$$

$$(+\uparrow)\Sigma F_y = F_3 + F_4 - W1g = 0$$

$$F_3 + 216 \text{ lbs} - 420 \text{ lbs} = 0$$

Weight at front tire,  $F_3 = 204 \text{ lbs}$

Table 10 – Inclined Calculations

<i>AT AN ANGLE</i>			
Angle relative to flat ground (°)	9.051	0.157965	rad
Flat front tire weight, F1 (lb)	197		
Flat back tire weight, F2 (lb)	223		
Weight at front tire, F3 (lb)	204		
Weight at back tire, F4 (lb)	216		
Weight Ratio	0.883		
CG Dist, a (in)	30.00		
CG Dist, b (in)	8.29		
Dist, c (in)	28.32		

**WEIGHT OF FRONT WHEEL AT VARIOUS INCLINATIONS**

Note that the calculations above were taken when the rear wheel was raised. The calculations following were calculated as if the front wheel were to be raised in order to determine how much weight the front wheel bears at various angles of inclination. It is also using the weight of the motorcycle with only one gallon of gas (412.03 lbs.), as opposed to the weight of 420 lbs. which was found when measuring the motorcycle when level as well as elevated.

$$b = \frac{(W * a - F_4 * l) \cos\theta}{W * \sin\theta}, \text{ solving for } F_4$$

$$F_4 = \frac{-\left(\frac{b * W * \sin\theta}{\cos\theta}\right) + W * (l - a)}{l}$$

$$F_4 = \frac{-\left(\frac{8.29 \text{ in} * 412.03 \text{ lbs} * \sin(30^\circ)}{\cos(30^\circ)}\right) + 412.03 \text{ lbs} * (56.5 \text{ in} - 30.0 \text{ in})}{56.5 \text{ in}}$$

*Weight of Front Wheel @ 30° incline, F<sub>4</sub> = 158.38 lbs*

Table 11 – Front Tire Weight at Various Angles

<b>Weight on Fixture vs. Angle</b>			
Angle (deg)	Angle (rad)	Weight at front tire (lbs)	Max. Design Fixture Weight (lbs)
5	0.09	187.98	12.02
10	0.17	182.61	17.39
15	0.26	177.07	22.93
20	0.35	171.27	28.73
25	0.44	165.09	34.91
30	0.52	158.38	41.62
35	0.61	150.95	49.05
40	0.70	142.56	57.44
45	0.79	132.84	67.16

## STRUCTURAL DESIGN CALCULATIONS (10)

### Main Weldments

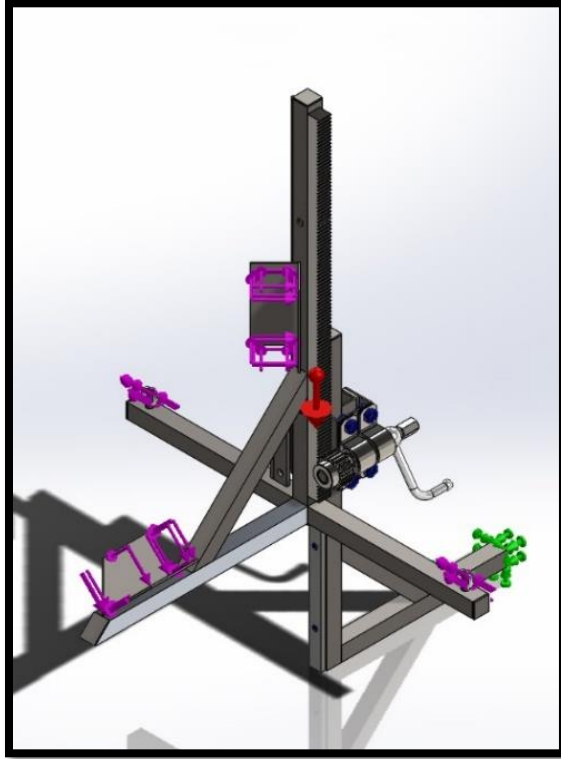


Figure 21 – Loading Conditions

Table 12 – Given Values for Both Frames

<b>Raised Position</b>	
<b>Given Values for M-Frame</b>	
Radius of Front Tire (in)	11.55
Tube Thickness (in)	1.25
Angle Distance (in)	1.5
M-Frame CG dist, m (in)	5
Pin Distance, p (in)	7.375
Roller Distance, r (in)	3.9375
<b>Given Values for C-Frame</b>	
C-Frame CG dist, c (in)	5
Pin Distance, p (in)	18.3
Roller Distance, r (in)	15.575
Hitch Distance, h1 (in)	9.625
Hitch Length, h2 (in)	5
Tube Diff. t (in)	11.69

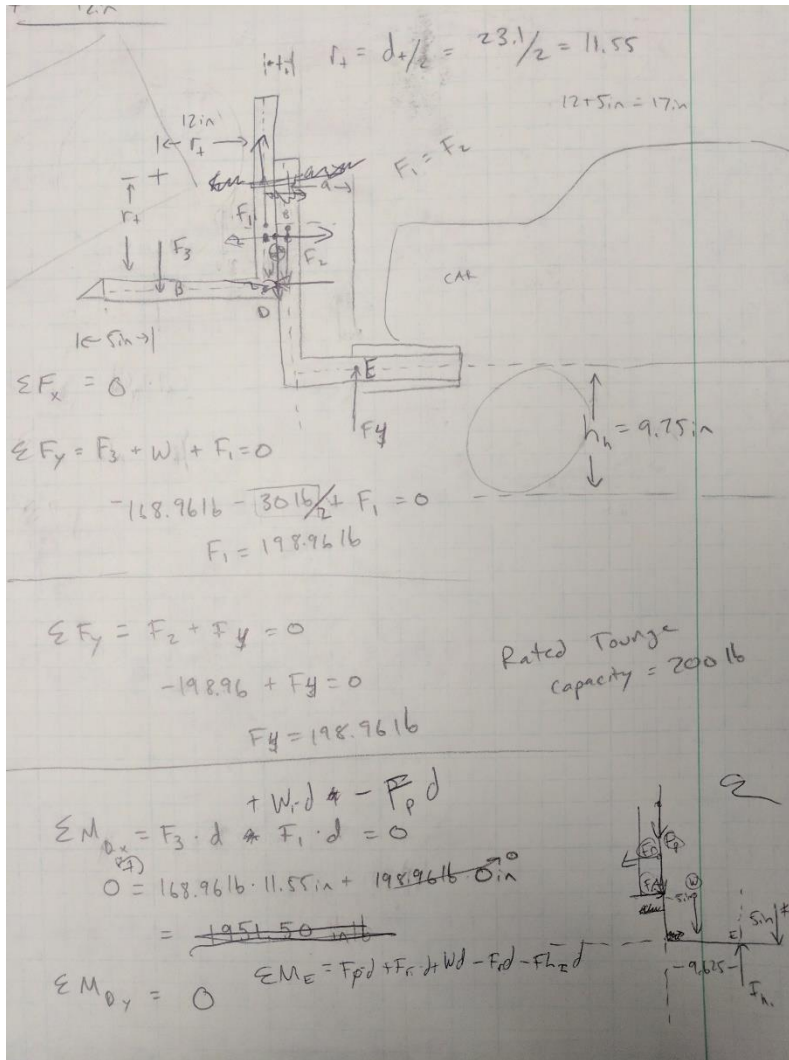


Figure 22 – Structural Calculations

Table 13 – Structural Calculations for Both Frames

Calculations		
M-Frame	Sum Forces in Y	0
	F3 (lbs) for 30° Angle	158.38
	M-Frame Weight (lbs)	16.14
	Fp (lbs)	174.51
	Moment at B (in*lb)	0
	Fr1 (lbs)	654.29
	Sum Forces in X	0
	Fr2 = Fr1	654.29
C-Frame	Sum Forces in X	0
	Fr2 (lbs)	654.29
	C-Frame Weight (lbs)	16.14
	Moment at E (in*lb)	0
	Fh2 (lbs)	2388.98
	Sum Forces in Y	0
	Fh1 (lbs)	2579.63
	Fh (lbs)	190.65

Pins

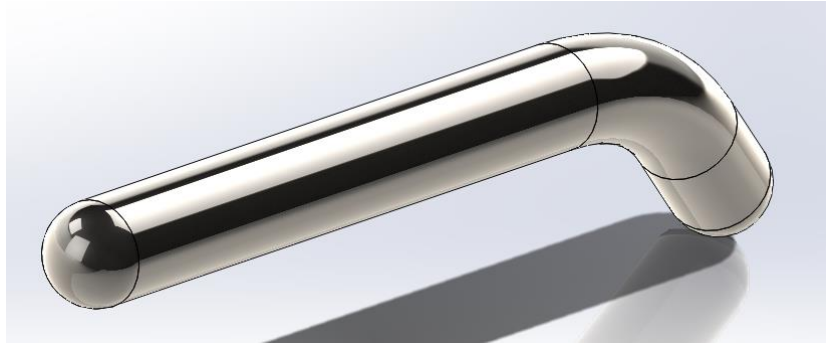


Figure 23 – McMASTER-CARR Hitch Pin #94563A812 (11)

Table 14 – Pin Specifications

Pin Specification	Rockwell B80
Diameter, D (in.)	0.5
Length, L (in)	2.5
Tensile Strength, Ts (psi)	72000
Area, A (in <sup>2</sup> )	0.785

$$\text{Shear Area, } A_s \text{ (in}^2\text{)} = \frac{\pi D^2 \text{ (in}^2\text{)}}{4}$$

$$A_s \text{ (in}^2\text{)} = \frac{\pi(0.5 \text{ in})^2}{4}$$

$$A_s = 0.393 \text{ in}^2$$

**Maximum Force, F (lbs)**

$$= \frac{\text{Total Design weight (lbs)} - 0.5 * \text{Design Fixture weight(lbs)}}{\# \text{ of Pins}}$$

$$F \text{ (lbs)} = \frac{200 \text{ lbs} - 0.5 * 41.62 \text{ lbs}}{2}$$

$$F = 89.59 \text{ lbs}$$

$$\text{Shear Stress, } \tau \text{ (psi)} = \frac{F \text{ (lbs)}}{A_s \text{ (in}^2\text{)}}$$

$$\tau \text{ (psi)} = \frac{89.59 \text{ lbs}}{0.393 \text{ in}^2}$$

$$\tau = 229.149 \text{ psi}$$

Table 15 – Pin Shear Stress Calculations

<b>Calculations</b>	
F1 (lbs)	89.59
F2 (lbs)	89.59
Shear Area, $A_s$ (in <sup>2</sup> )	0.393
Shear Stress, $\tau$ (psi)	228.149

**RACK AND PINION DESIGN CALCULATIONS (11) (12) (13)**

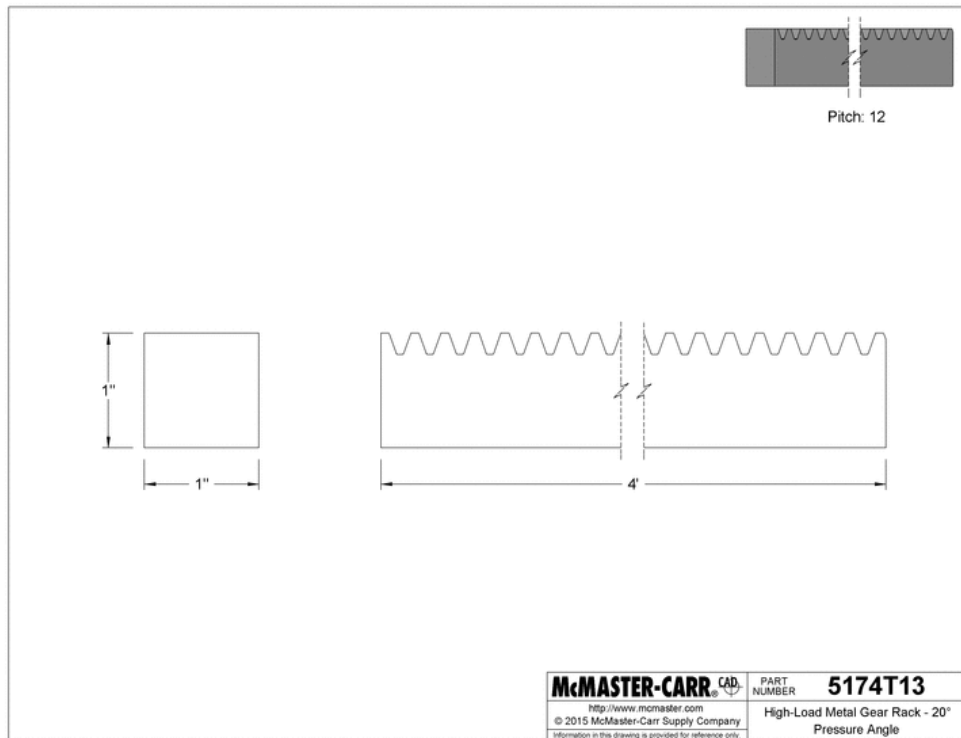


Figure 24 – McMASTER-CARR SS Rack #5174T13 (14)

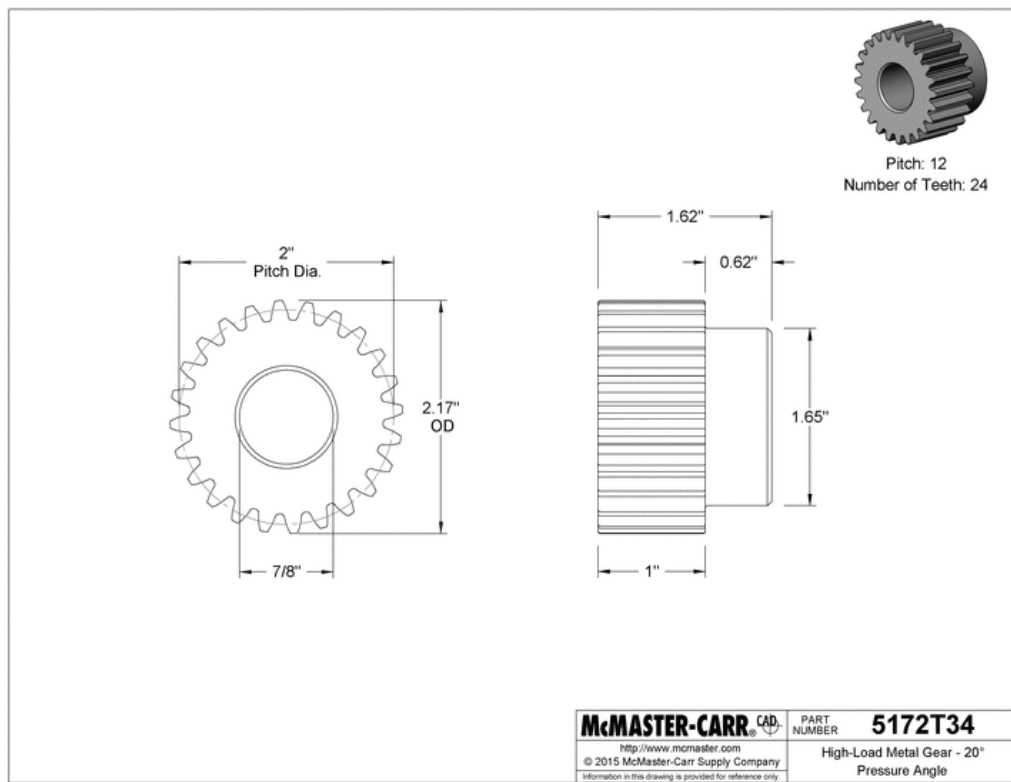


Figure 25 – McMASTER-CARR SS Pinion #5172T34 (14)

Table 16 – Rack and Pinion Given/Observed Values

Given			
Human Constant Power, P (hp/lb*ft/s)	0.1	55	lb*ft/s
Max Force on Tooth, Fr (lbs)	197		
Transmitted Force on Tooth, Ft (lbs)	185.1		

Table 17 – Initial Design Selections Tables

Rack		Pinion	
Pressure Angle, $\phi$ (°)	20	Pressure Angle, $\phi$ (°)	20
Diametral Pitch, Pd	12	Diametral Pitch, Pd	12
Face Width, Fw (in)	1	Face Width, Fw (in)	1
Height, H (in)	1	# of Teeth	24
		Pitch Diameter, Dp (in)	2
		For Shaft Dia. (in)	7/8

$$\text{Tangential Force, } F_t \text{ (lbs)} = F_r * \cos(\theta)$$

$$F_t \text{ (lbs)} = 197 \text{ lbs} * \cos(30^\circ)$$

$$F_t = 185.1 \text{ lbs}$$

$$\text{Torque, } T \text{ (in * lb)} = \frac{F_t * D_p}{2}$$

$$T \text{ (in * lb)} = \frac{185.1 \text{ lbs} * 2 \text{ in}}{2}$$

$$T = 185.1 \text{ in * lb}$$

$$\text{Rotational Speed of Pinion, } \omega_p \left( \frac{\text{rad}}{\text{s}} \right) = \frac{63000 * P(\text{hp})}{T \text{ (in * lb)}}$$

$$\omega_p \left( \frac{\text{rad}}{\text{s}} \right) = \frac{63000 * 0.1 \text{ hp}}{185.1 \text{ in * lb}}$$

$$\omega_p = 34.03 \frac{\text{rad}}{\text{s}}$$

$$\text{Transmitted Load, } W_t \text{ (lbs)} = \frac{2 * P \text{ (lb * ft/s)}}{D_p(\text{in}) * \omega_p(\text{rps})}$$

$$W_t \text{ (lbs)} = \frac{2 * 55 \text{ lb * ft/s}}{2 \text{ in} * 0.594 \text{ rps}}$$

$$W_t = 92.6 \text{ lbs}$$

$$\text{Linear Speed, } v_t \left( \frac{\text{ft}}{\text{s}} \right) = \frac{P \left( \frac{\text{lb ft}}{\text{s}} \right)}{W_t \text{ (lbs)}}$$

$$v_t \left( \frac{\text{ft}}{\text{s}} \right) = \frac{55 \frac{\text{lb ft}}{\text{s}}}{92.6 \text{ lbs}}$$

$$v_t = 0.594 \frac{ft}{s}$$

$$S_t = \left( \frac{W_t * P_d}{F * J} \right) K_o K_s K_m K_B K_v$$

$$S_t (psi) = \left( \frac{92.6 lbs * 12}{1 in * 0.37} \right) (1.3)(1)(1.289)(1)(1.05)$$

$$S_t = 5282 psi$$

$$J = 0.37, \text{ from Figure 9 - 17}$$

$$K_o = 1.3, \text{ from Table 9 - 5}$$

$$K_s = 1, \text{ from Table 9 - 6}$$

$$K_m = 1 + C_{pf} + C_{ma}$$

$$K_m = 1 + 0.025 + 0.264$$

$$K_m = 1.289$$

$$C_{pf} = \frac{F}{10 * D_p} - 0.025, \text{ from Figure 9 - 18}$$

$$C_{pf} = \frac{1}{10 * 2 in} - 0.025$$

$$C_{pf} = 0.025$$

$$C_{ma} = 0.247 + 0.0167 * F - 0.765 * 10^{-4} * F^2, \text{ from Figure 9 - 19}$$

$$C_{ma} = 0.247 + 0.0167 * 1 in - 0.765 * 10^{-4} * (1 in)^2$$

$$C_{ma} = 0.264$$

$$K_B = 1, \text{ from Figure 9 - 20 based on } m_B$$

$$m_B = \frac{t_r}{h_t}$$

$$m_B = \frac{(1.86 - 1)/2}{(2.13 - 1.86)/2}$$

$$m_B = 3.185$$

$$K_v = 1.05 \text{ from Figure 9 - 21 based on } v_t$$

$$\text{Allowable Bending Stress, } S_{at} = 27,000 psi, \text{ from Figure 9 - 10}$$

$$\text{Adjusted Allowable Bending Stress, } S'_{at} = S_{at} * \frac{Y_N}{(SF * K_R)}$$

$$S'_{at} = 27,000 psi * \frac{1.6}{(1.25 * 1.25)}$$

$$S'_{at} = 27,648 \text{ psi}$$

**Stress Cycle Factor,  $Y_N = 1.6$ , from Figure 9 – 22 based on  $N_C$**

**Number of Estimated Loading Cycles,  $N_C = 60 * L * n * q$**

$$N_C = 60 * 10 * 60 \text{ rpm} * 24$$

$$N_C = 142.6$$

**$K_R = 1.25$ , from Table 9 – 8**

**SF = 1.25 (chosen)**

Note that all references in the below table are directed to the Machine Elements in Mechanical Design book referenced above.

Table 18 – Final Rack and Pinion Design Calculations

<b>Calculations</b>			
Torque, T (in*lb)	185.1		
Transmitted Load, Wt (lbs)	92.6		
Linear Speed, Vt (ft/s)	0.594	7.128	in/s
Height required for 30° Angle (in)	28.25	2.354	ft
Min. Distance to Cover (in)	18.5	1.542	ft
Pitch Diameter, Dp (in)	2		
Rotational Speed of pinion, $\omega_p$ (rad/s)	34.03	0.594	rps
Number of Pinion Teeth, Np	24		
Bending Stress Number, St (psi)	5282		
Overload Factor, Ko	1.3	Table 9-5	
Size Factor, Ks	1	Table 9-6	
Load Distribution Factor, Km	1.289		
Pinion Proportion Factor, Cpf	0.025	Figure 9-18	
Mesh Alignment Factor, Cma	0.264	Figure 9-19	
Rim Thickness Factor, KB	1	Figure 9-20	
Backup Ratio, mB	3.185		
Dynamic Factor, Kv	1.05	Figure 9-21	
Geometry Factor, J	0.37	Fig. 9-17	
Face Width, F (in)	1		
Adj. Allowable Bending Stress, S'at (psi)	27648		
Allowable Bending Stress, Sat (psi)	27000		
Stress Cycle Factor, Yn	1.6	Figure 9-22	
Number of Loading Cycles, Nc	142.6		
Safety Factor, SF	1.25		
Reliability Factor, Kr	1.25	Table 9-8	

**BEARING DESIGN CALCULATIONS (11)**

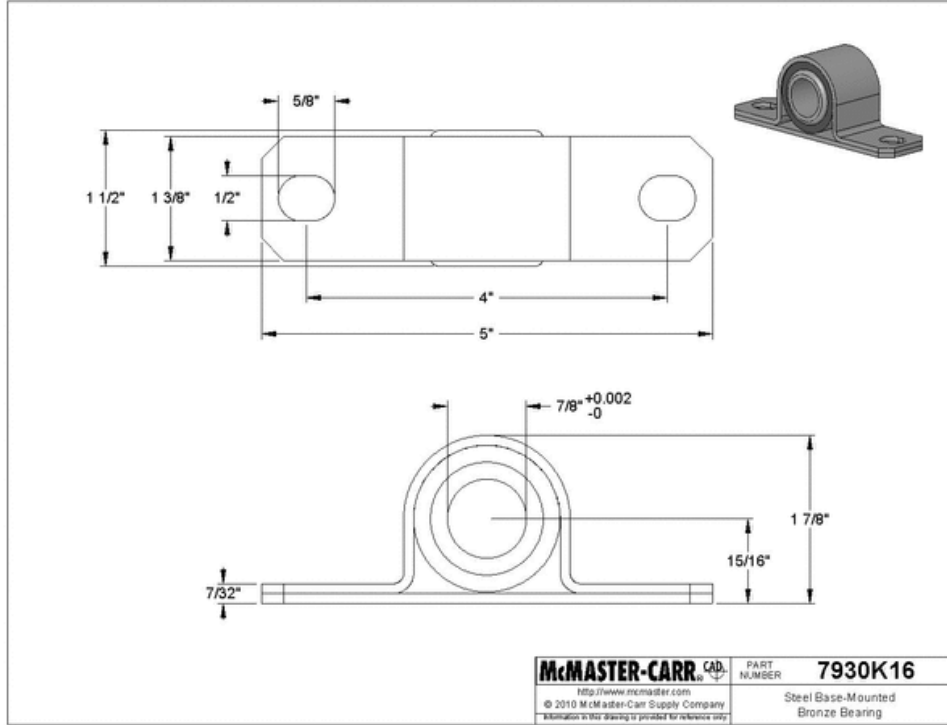


Figure 26 – McMASTER-CARR Bearing #7930K16 (14)

Bearing Design

$$\frac{L_2}{L_1} = \left(\frac{P_1}{P_2}\right)^k$$

$k = 3.00$  ball bearings  
 $k = 3.33$  roller

$$L_2 = L_1 \left(\frac{P_1}{P_2}\right)^k = 10^6 \left(\frac{2500 \text{ lbs}}{349.12 \text{ lbs}}\right)^{3.00} = 3.67 \times 10^8$$

$$L_d = \boxed{5000} \text{ hrs.} (60 \text{ rpm}) (60 \text{ min/hr}) = 1.8 \times 10^7 \text{ rev.}$$

$$C = Pd \left(\frac{L_d}{10^6}\right)^{1/k} = 349.12 \text{ lbs} \left(\frac{1.8 \times 10^7}{10^6}\right)^{1/3.0}$$

$$C = 914.95 \text{ lbs}$$

or

$$C = Pd \frac{F_L}{F_N} = 349.12 \left(\frac{7.15}{0.825}\right)$$

$$C = 909.82 \text{ lbs}$$

Figure 27 – Initial Bearing Design Calculations

Table 19 – Final Bearing Calculations

k	3
Bearing Life, L1	1.00E+07
P1	2500
P2/Pd	349.12
Overall Life, L2	3.67E+09

Table 20 – Final Bearing Calculations 2

Required Life (hrs)	5000	
Rotational Speed (rpm)	60	
Design Life, Ld (rev)	1.80E+07	
C	914.95	or 909.82

**SHAFT DESIGN CALCULATIONS (11)**

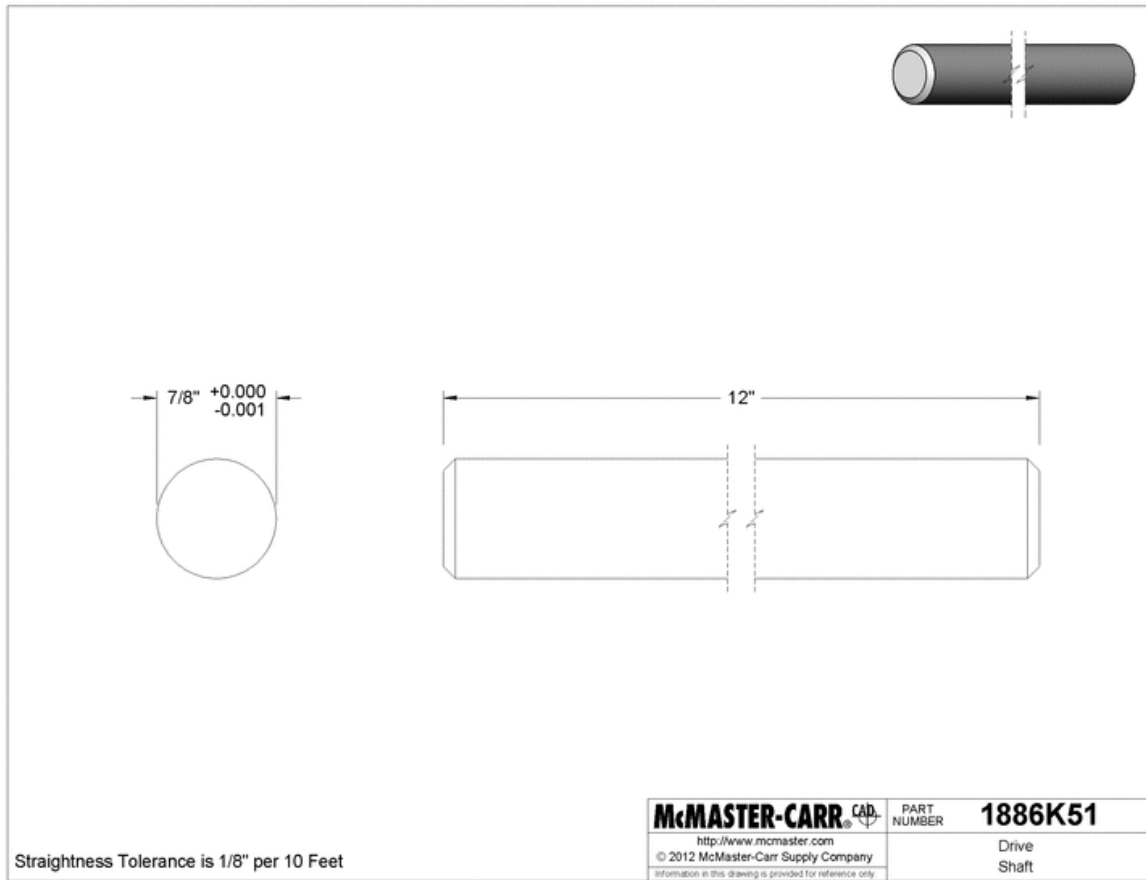


Figure 28 – McMASTER-CARR Drive Shaft #1886K51

Table 21 – Shaft Given Information

<b>Material</b>	
1045 Carbon Steel	
Rockwell C68	
Yield Strength, Sy (psi)	45,000
Ultimate Strength, Su (psi)	81,900
<b>Shaft Information</b>	
Distance 1, D1 (in)	2.09
Distance 2, D2 (in)	1.63
Distance 3, D3 (in)	2.19
Torque, T (in*lb)	179.19
Diameter, D (in)	0.875

Type equation here.

Table 22 – Shaft Design Values

From Tables and Figures		
Endurance Strength, $S_n$ (psi)	30000	Figure 5-8
Estimated Endurance Strength, $S_n'$ (psi)	20001	
Cs	0.889	Figure 5-9
Reliability Factor, CR	0.75	Table 5-1

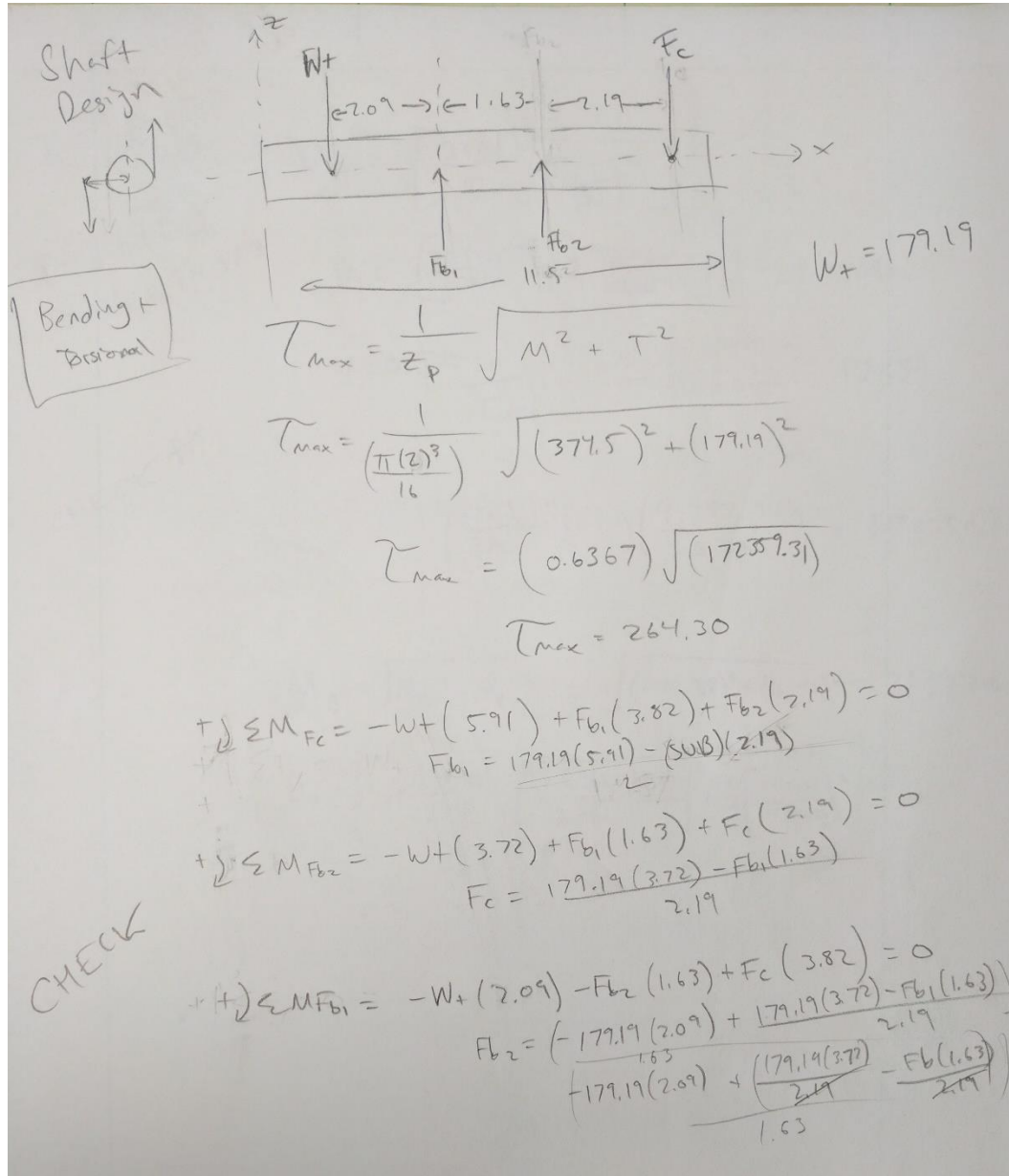
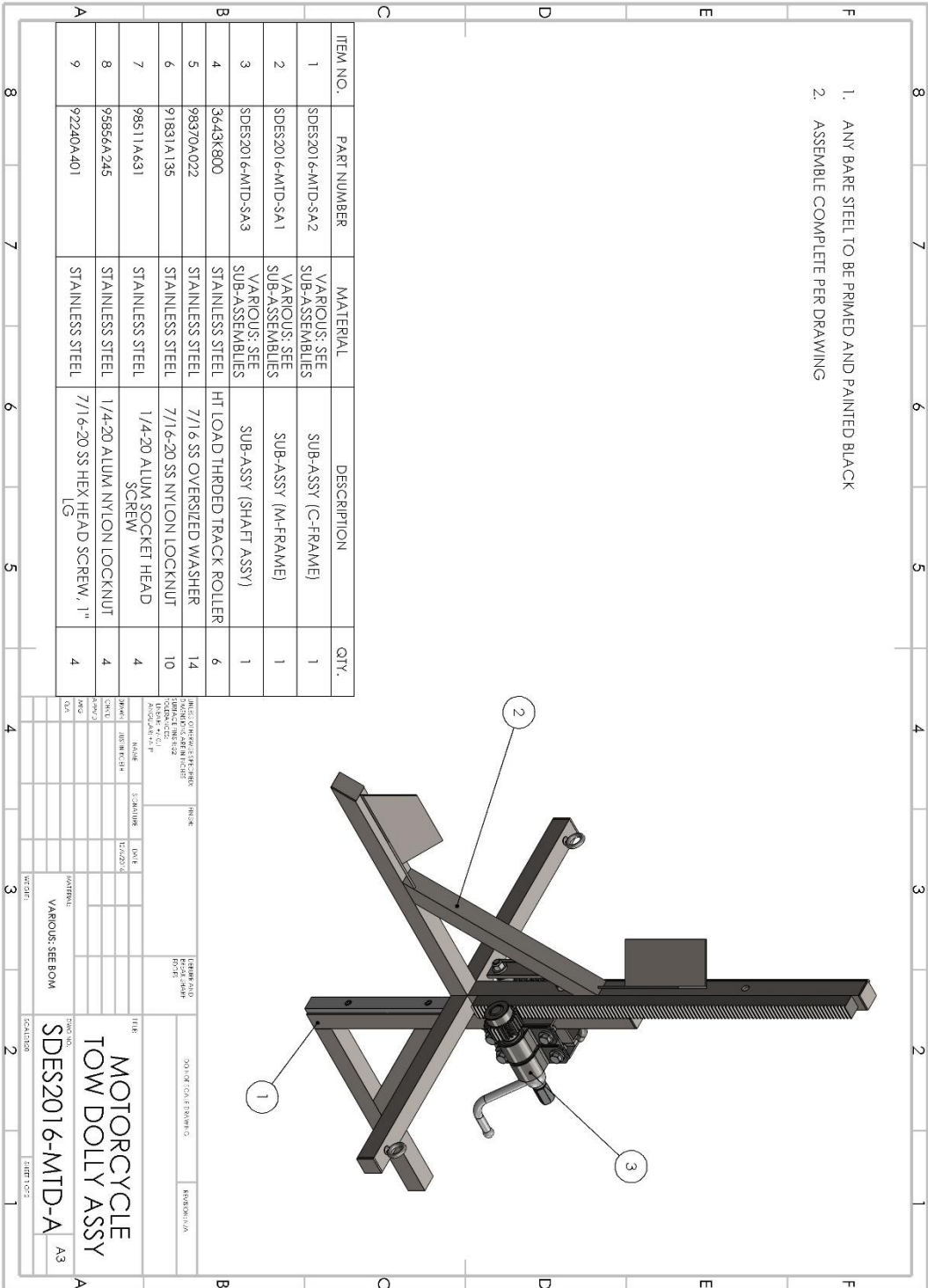


Figure 29 – Initial Shaft Design Calculations

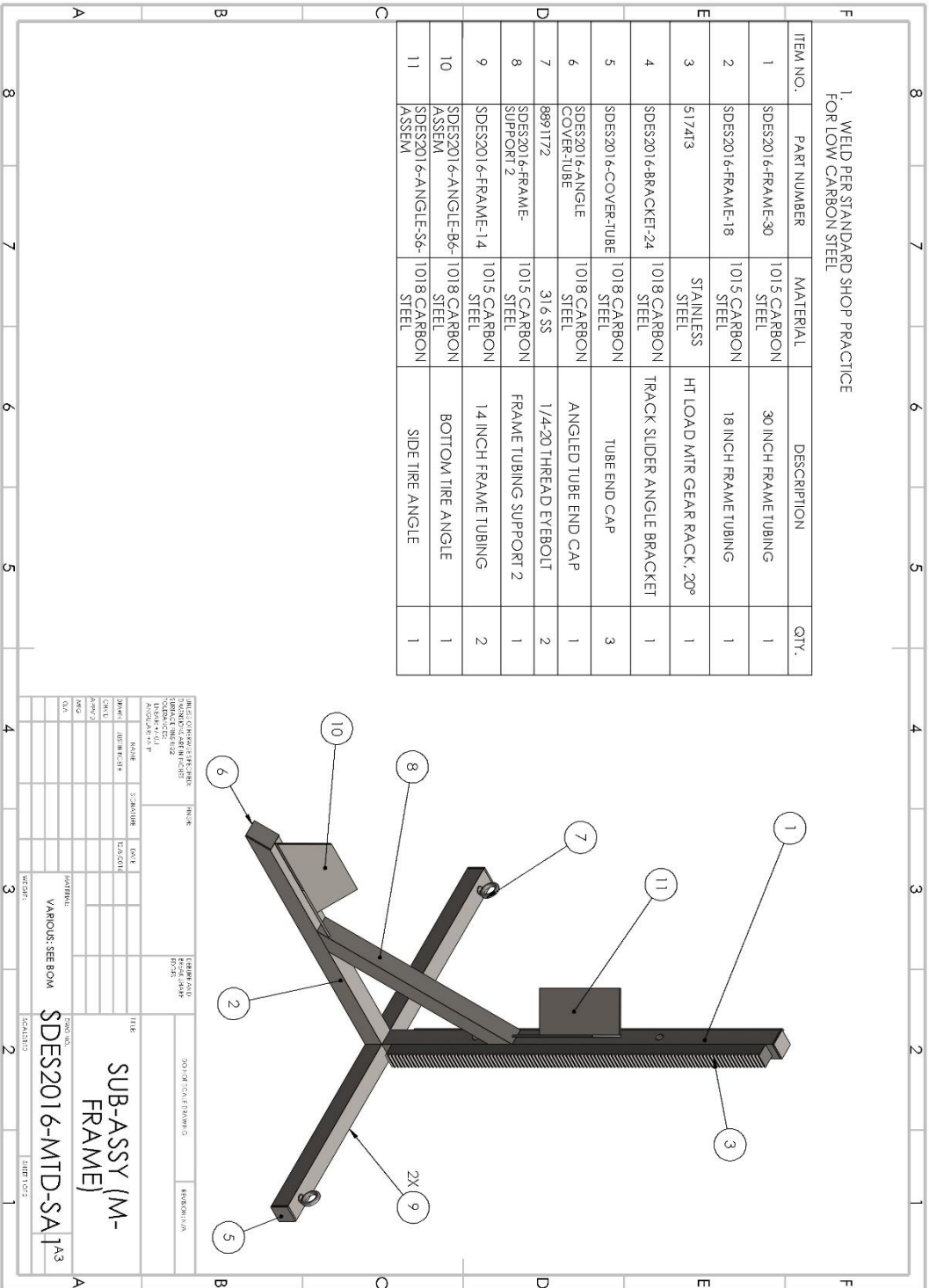
Table 23 – Final Shaft Calculations

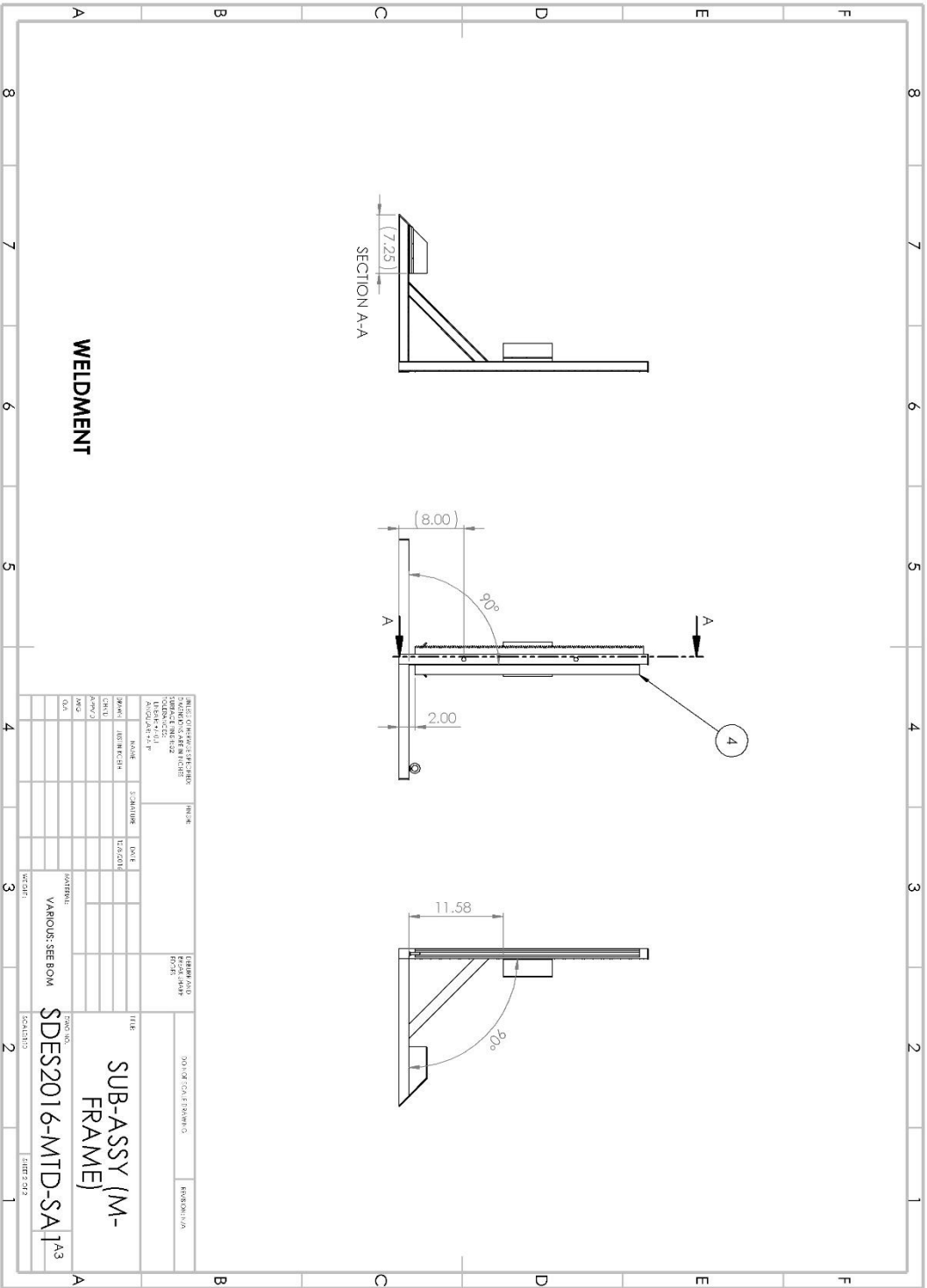
<b>Calculations</b>	
Max Weight, Wt (lbs)	179.19
Force on Bearing 1, Fb1 (lbs)	-487.89
Force on Bearing 2, Fb2 (lbs)	-2238.23
Force from Crank, Fc (lbs)	667.5032
Moment at A, (in*lb)	0
Moment at B, (in*lb)	374.50
Moment at C, (in*lb)	-1814.93
Moment at D, (in*lb)	0
Section Modulus, Zp (in <sup>3</sup> )	0.13
Maximum Shear Stress, τmax (in*lbs)	13864.79

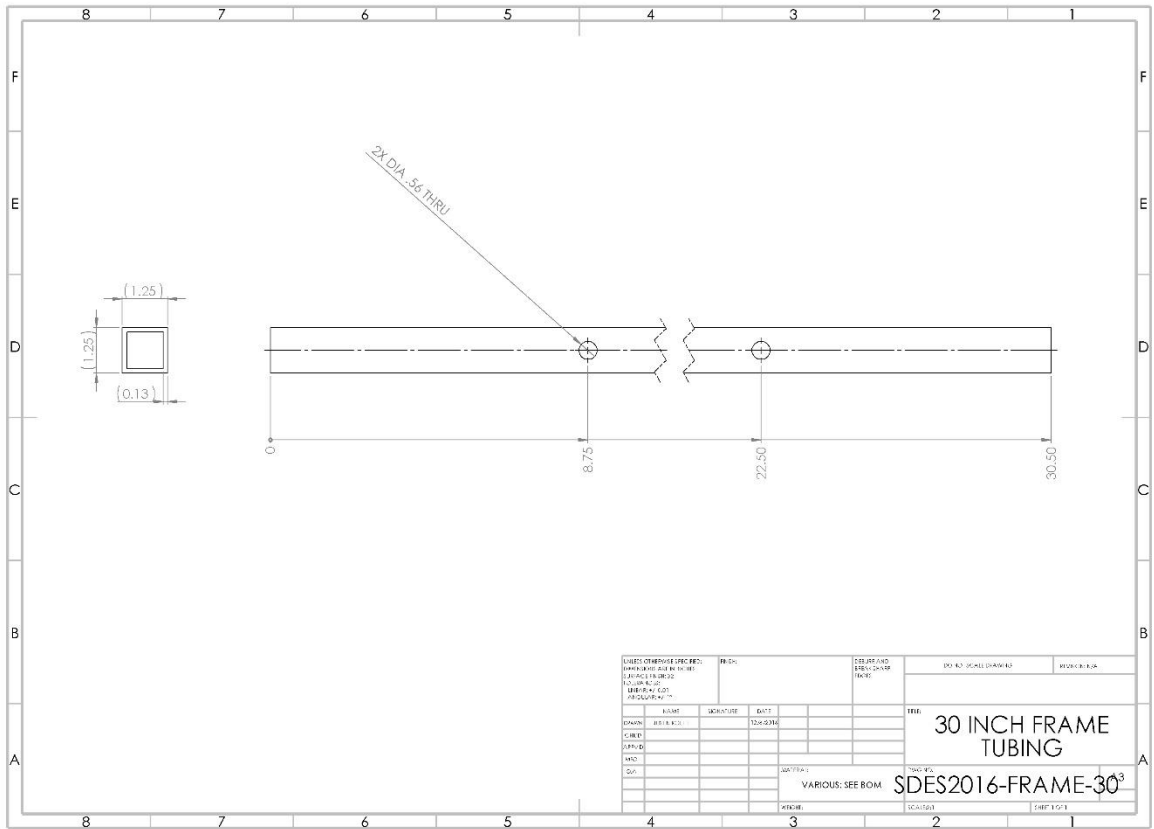
# APPENDIX I – FINAL ASSEMBLY AND DRAWINGS



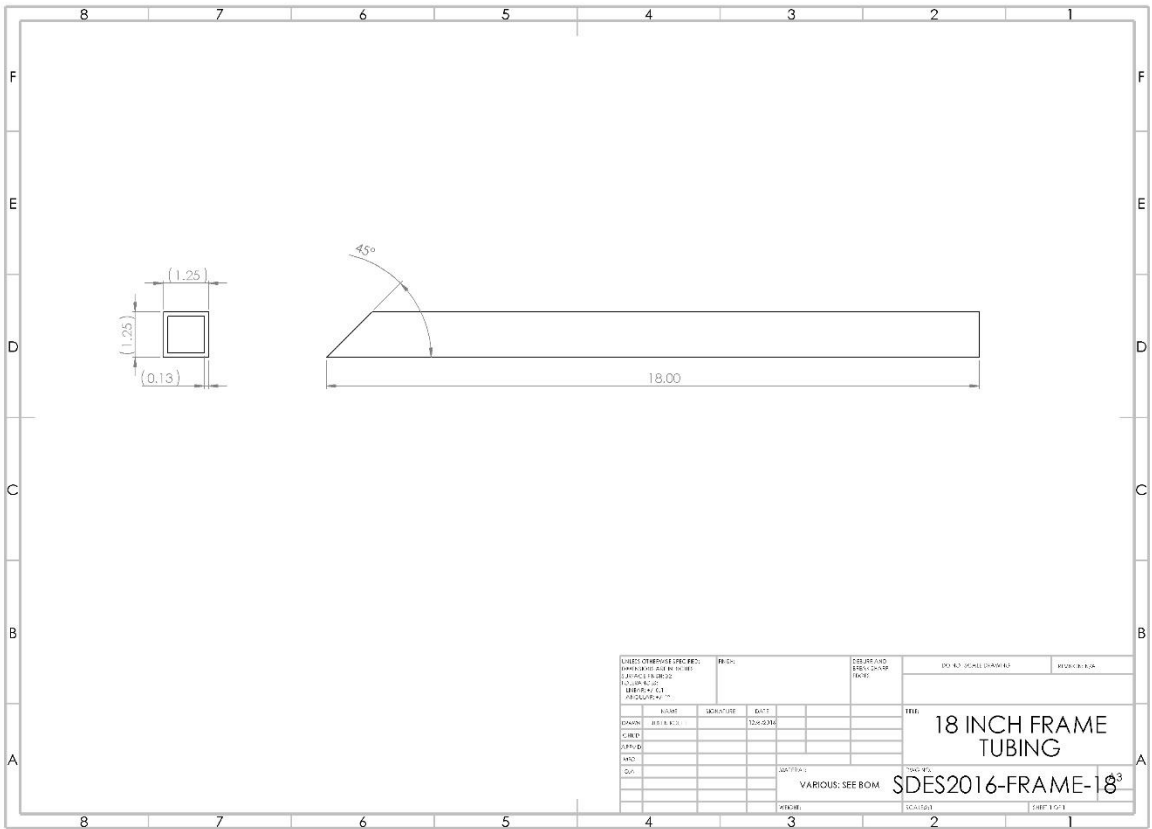








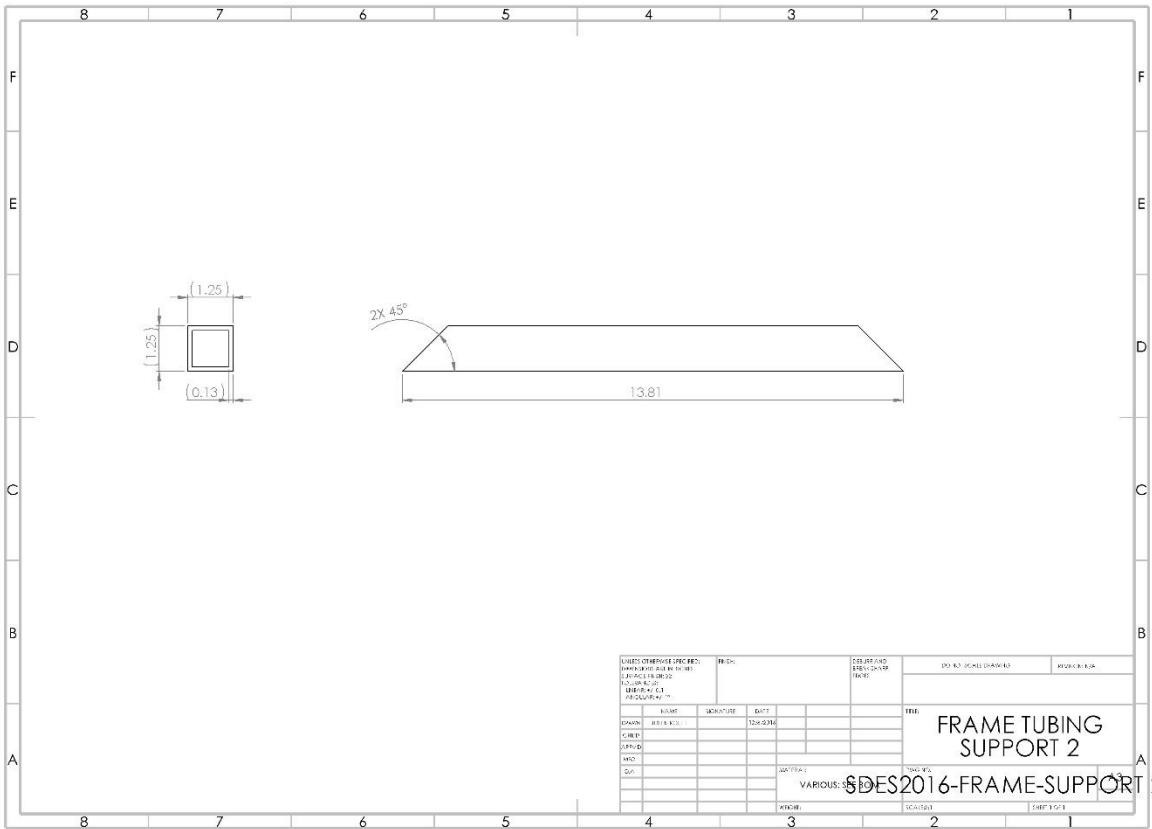
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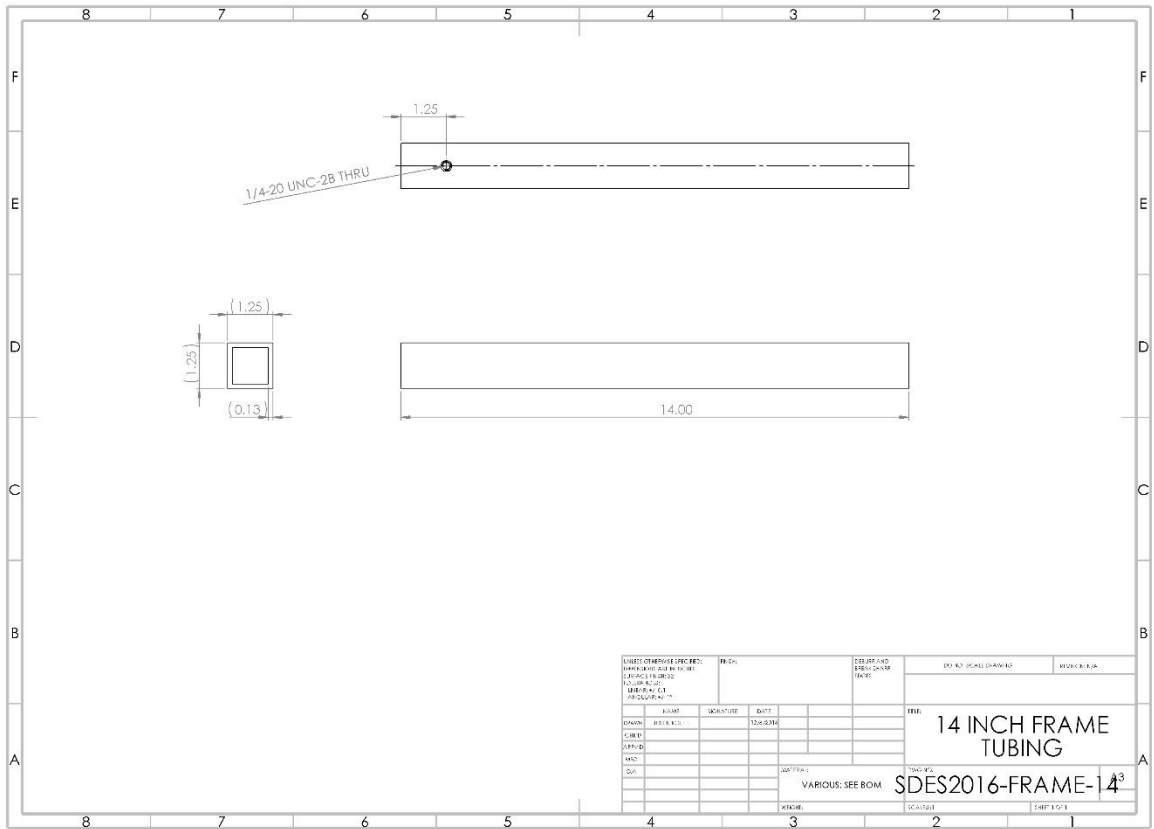
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NAME: _____ TITLE: _____ DATE: _____ BY: _____	SIGNATURE: _____ TITLE: _____	DATE: _____	TITLE: _____	18 INCH FRAME TUBING
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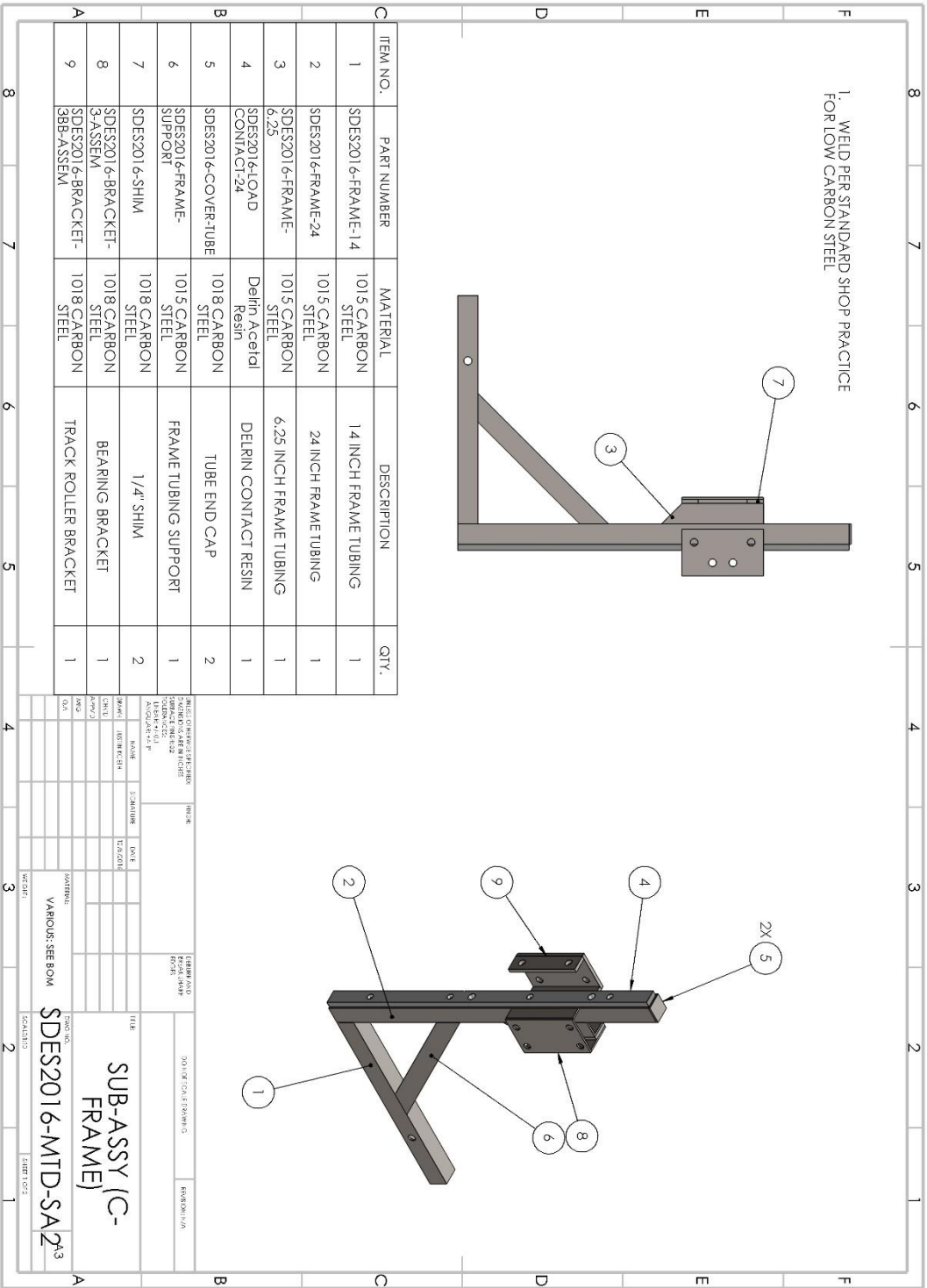




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VARIOUS: _____			SHEET NO.:	<b>SDS2016-FRAME-SUPPORT 2</b>	
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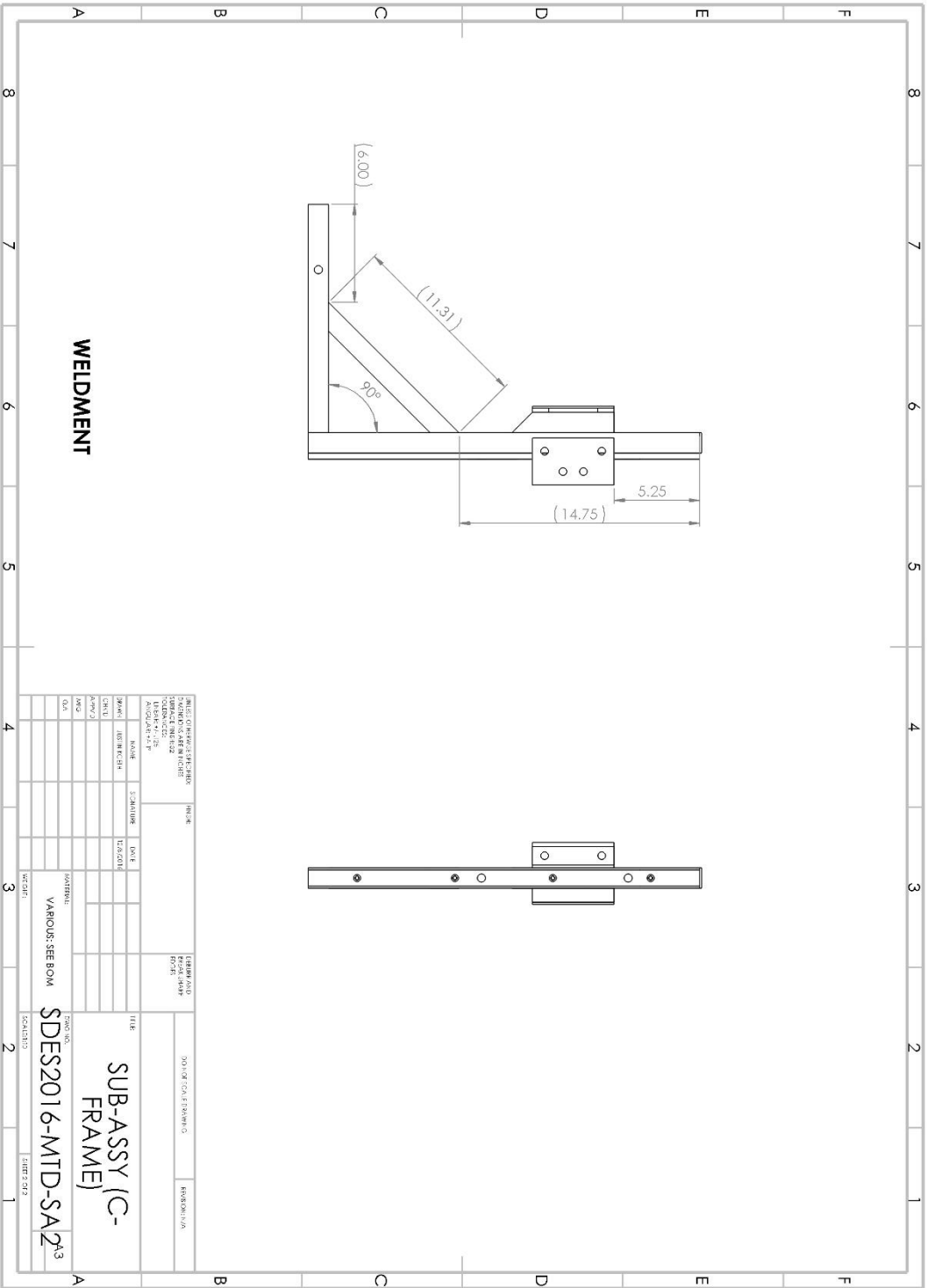


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FINISH:		REV:	DATE:	BY:	SDES2016-FRAME-14 <sup>3</sup>	
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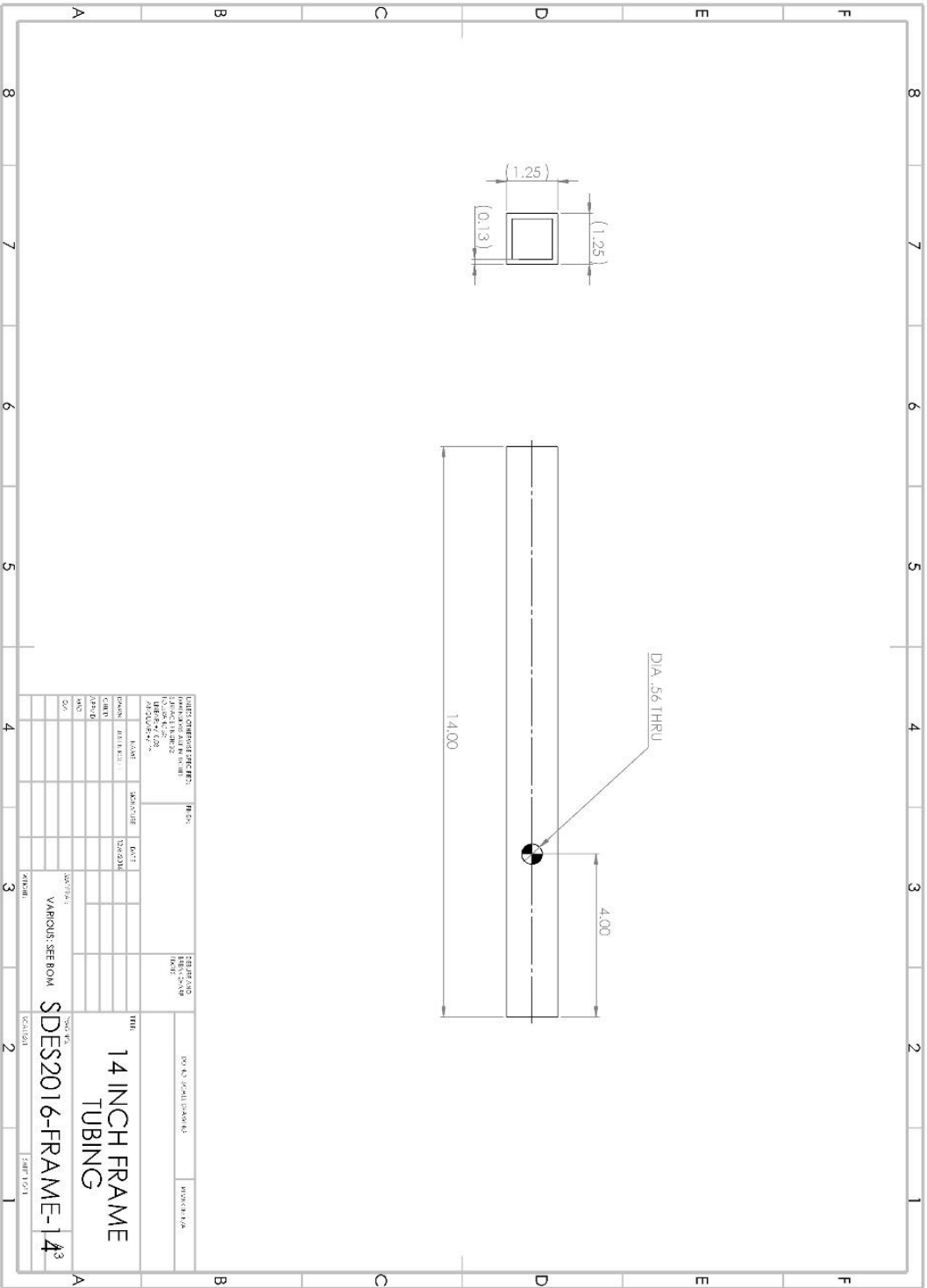
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1	SDES2016-FRAME-14	1015 CARBON STEEL	14 INCH FRAME TUBING	1
2	SDES2016-FRAME-24	1015 CARBON STEEL	24 INCH FRAME TUBING	1
3	SDES2016-FRAME-6.25	1015 CARBON STEEL	6.25 INCH FRAME TUBING	1
4	SDES2016-LOAD CONTACT-24	Delrin Acetal Resin	DELRIN CONTACT RESIN	1
5	SDES2016-COVER-TUBE SUPPORT	1018 CARBON STEEL	TUBE END CAP	2
6	SDES2016-FRAME-SUPPORT	1015 CARBON STEEL	FRAME TUBING SUPPORT	1
7	SDES2016-SHIM	1018 CARBON STEEL	1/4" SHIM	2
8	SDES2016-BRACKET-ASSEM	1018 CARBON STEEL	BEARING BRACKET	1
9	SDES2016-BRACKET-3BB-ASSEM	1018 CARBON STEEL	TRACK ROLLER BRACKET	1

MATERIAL SPECIFICATION		MATERIAL		MATERIAL	
ITEM NO.	DESCRIPTION	ITEM NO.	DESCRIPTION	ITEM NO.	DESCRIPTION
1	1015 CARBON STEEL	2	1018 CARBON STEEL	3	1015 CARBON STEEL
4	DELRIN ACETAL RESIN	5	1018 CARBON STEEL	6	1015 CARBON STEEL
7	1018 CARBON STEEL	8	1018 CARBON STEEL	9	1018 CARBON STEEL
DRAWN BY: [blank]		CHECKED BY: [blank]		APPROVED BY: [blank]	
DATE: [blank]		DATE: [blank]		DATE: [blank]	
SCALE: [blank]		SCALE: [blank]		SCALE: [blank]	
SHEET: [blank] OF [blank]		SHEET: [blank] OF [blank]		SHEET: [blank] OF [blank]	
PROJECT: VARIOUS: SEE BOM		PROJECT: VARIOUS: SEE BOM		PROJECT: VARIOUS: SEE BOM	
DRAWING NO: SDES2016-MTD-SAP3		DRAWING NO: SDES2016-MTD-SAP3		DRAWING NO: SDES2016-MTD-SAP3	
TITLE: SUB-ASSY (C-FRAME)		TITLE: SUB-ASSY (C-FRAME)		TITLE: SUB-ASSY (C-FRAME)	



**WELDMENT**

TITLE: SUB-ASSY (C-FRAME) DRAWN BY: SDES2016-MTD-SAP3 CHECKED BY: [blank] DATE: [blank]		DATE: [blank]	
PROJECT: [blank]		SHEET: [blank]	
PART: [blank]		QUANTITY: [blank]	
MATERIAL: [blank]		FINISH: [blank]	
TOLERANCES: [blank]		DIMENSIONS: [blank]	
SURFACE FINISH: [blank]		WEIGHT: [blank]	
ANNOTATIONS: [blank]		COMMENTS: [blank]	
NAME: [blank]		TITLE: [blank]	
JOB NUMBER: [blank]		DATE: [blank]	
SHEET: [blank]		TOTAL SHEETS: [blank]	
DATE: [blank]		VARIANTS: SEE BOM	
[blank]		SCHEDULE: [blank]	



**UNIT COMPONENTS:**

QTY	DESCRIPTION	UNIT	PRICE	TOTAL
1	14 INCH FRAME TUBING			

**VARIOUS: SEE ROOM**

**SDS2016-FRAME-143**

**14 INCH FRAME TUBING**

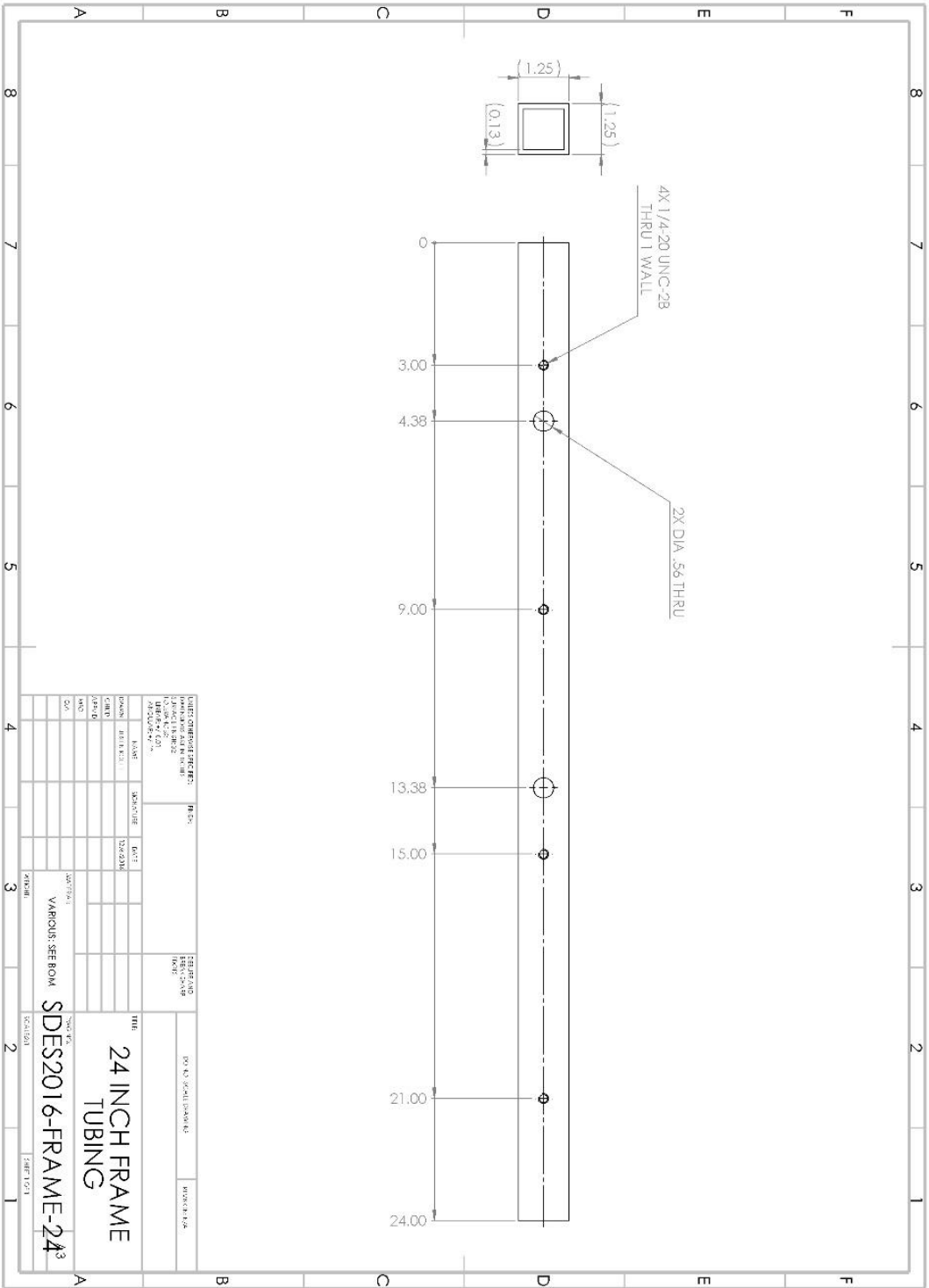
**VARIOUS: SEE ROOM**

**SDS2016-FRAME-143**

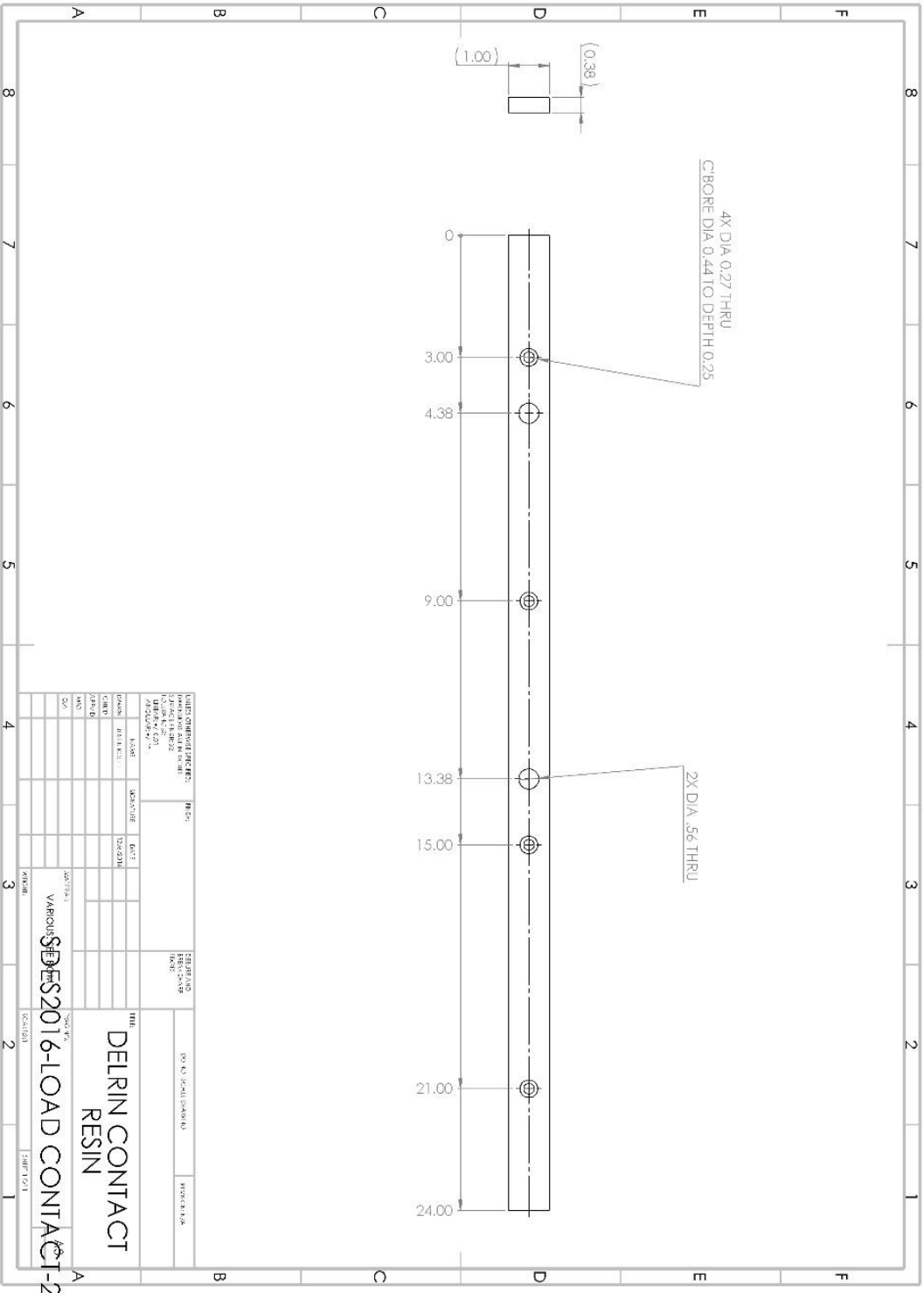
**VARIOUS: SEE ROOM**

8 7 6 5 4 3 2 1

A B C D E F



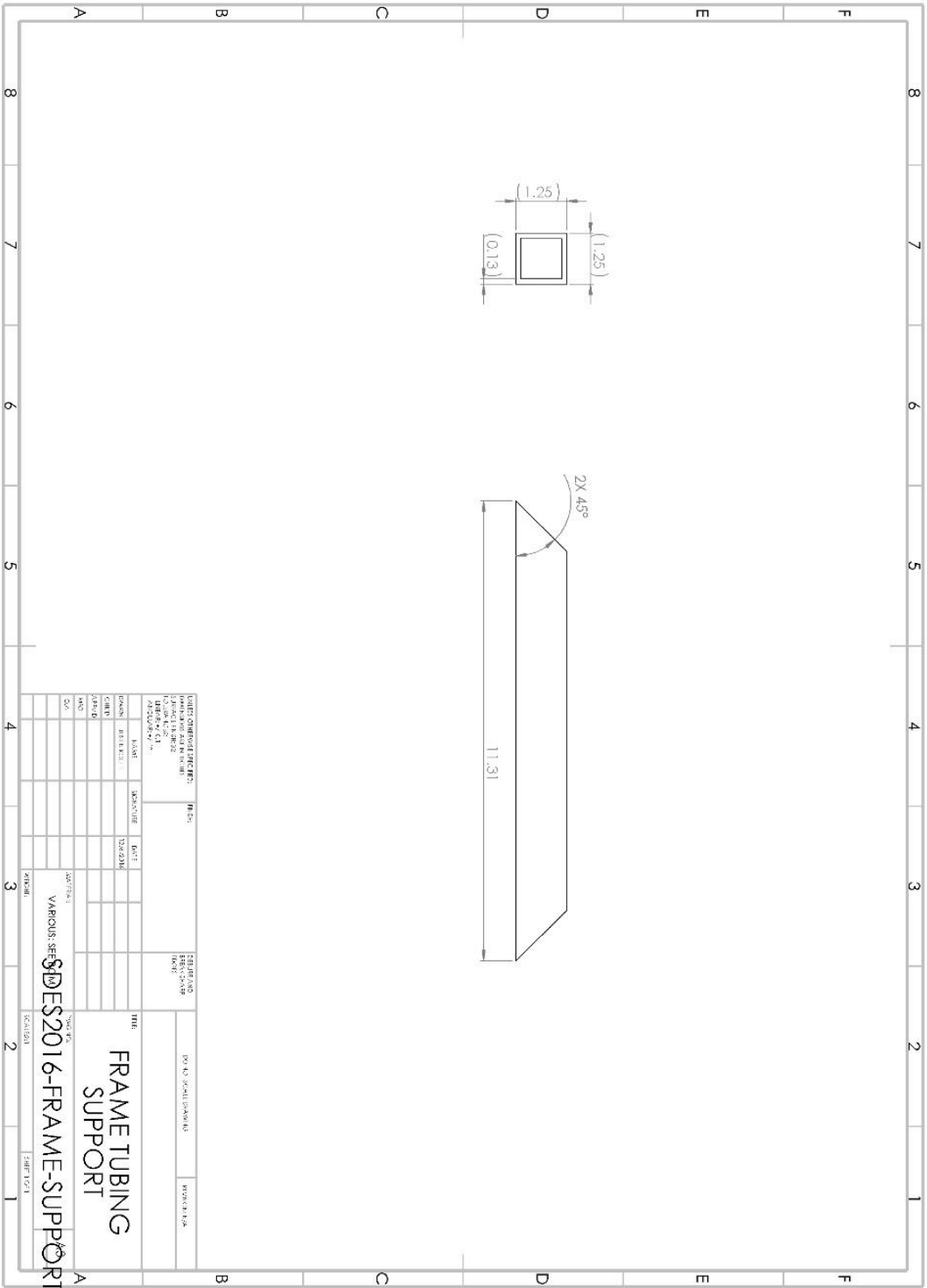




UNIT CONVERSIONS:				IN TO		MM TO		
IN	MM	MM	IN	MM	IN	MM	IN	
1/8"	3.175	3.175	1/4"	6.350	1/2"	12.700	3/4"	19.050
1/2"	12.700	12.700	3/4"	19.050	1"	25.400	1 1/4"	31.750
1"	25.400	25.400	1 1/4"	31.750	1 1/2"	38.100	1 3/4"	44.450
1 1/4"	31.750	31.750	1 3/4"	44.450	2"	50.800	2 1/4"	60.325
1 1/2"	38.100	38.100	2"	50.800	2 1/2"	63.500	2 3/4"	69.850
1 3/4"	44.450	44.450	2 1/4"	60.325	3"	76.200	3 1/4"	85.725
2"	50.800	50.800	2 3/4"	69.850	3 1/2"	88.900	3 3/4"	95.250
2 1/4"	60.325	60.325	3"	76.200	4"	101.600	4 1/4"	111.425
2 1/2"	63.500	63.500	3 1/2"	88.900	4 1/2"	113.025	4 3/4"	119.375
2 3/4"	69.850	69.850	4"	101.600	5"	127.000	5 1/4"	136.825
3"	76.200	76.200	4 1/2"	113.025	5 1/2"	139.700	5 3/4"	146.050
3 1/4"	85.725	85.725	5"	127.000	6"	152.400	6 1/4"	162.125
3 1/2"	88.900	88.900	5 1/2"	139.700	6 1/2"	165.100	6 3/4"	171.450
3 3/4"	95.250	95.250	6"	152.400	7"	177.800	7 1/4"	187.825
4"	101.600	101.600	6 1/2"	165.100	7 1/2"	190.500	7 3/4"	197.150
4 1/4"	111.425	111.425	7"	177.800	8"	203.200	8 1/4"	213.625
4 1/2"	113.025	113.025	7 1/2"	190.500	8 1/2"	216.150	8 3/4"	223.000
4 3/4"	119.375	119.375	8"	203.200	9"	228.600	9 1/4"	239.025
5"	127.000	127.000	8 1/2"	216.150	9 1/2"	241.325	9 3/4"	248.950
5 1/4"	136.825	136.825	9"	228.600	10"	254.000	10 1/4"	264.425
5 1/2"	139.700	139.700	9 1/2"	241.325	10 1/2"	266.675	10 3/4"	273.800
5 3/4"	146.050	146.050	10"	254.000	11"	279.400	11 1/4"	289.825
6"	152.400	152.400	10 1/2"	266.675	11 1/2"	292.125	11 3/4"	299.200
6 1/4"	162.125	162.125	11"	279.400	12"	304.800	12 1/4"	314.625
6 1/2"	165.100	165.100	11 1/2"	292.125	12 1/2"	317.500	12 3/4"	324.000
6 3/4"	171.450	171.450	12"	304.800	13"	330.200	13 1/4"	339.425
7"	177.800	177.800	12 1/2"	317.500	13 1/2"	343.025	13 3/4"	348.800
7 1/4"	187.825	187.825	13"	330.200	14"	355.600	14 1/4"	364.225
7 1/2"	190.500	190.500	13 1/2"	343.025	14 1/2"	368.500	14 3/4"	373.600
7 3/4"	197.150	197.150	14"	355.600	15"	381.200	15 1/4"	389.025
8"	203.200	203.200	14 1/2"	368.500	15 1/2"	394.125	15 3/4"	398.400
8 1/4"	213.625	213.625	15"	381.200	16"	406.400	16 1/4"	413.825
8 1/2"	216.150	216.150	15 1/2"	394.125	16 1/2"	419.325	16 3/4"	423.200
8 3/4"	223.000	223.000	16"	406.400	17"	431.600	17 1/4"	438.625
9"	228.600	228.600	16 1/2"	419.325	17 1/2"	444.500	17 3/4"	448.000
9 1/4"	239.025	239.025	17"	431.600	18"	457.200	18 1/4"	463.425
9 1/2"	241.325	241.325	17 1/2"	444.500	18 1/2"	470.125	18 3/4"	472.800
9 3/4"	248.950	248.950	18"	457.200	19"	482.800	19 1/4"	488.225
10"	254.000	254.000	18 1/2"	470.125	19 1/2"	495.725	19 3/4"	497.600
10 1/4"	264.425	264.425	19"	482.800	20"	508.000	20 1/4"	513.025
10 1/2"	266.675	266.675	19 1/2"	495.725	20 1/2"	520.925	20 3/4"	522.400
10 3/4"	273.800	273.800	20"	508.000	21"	533.600	21 1/4"	537.825
11"	279.400	279.400	20 1/2"	520.925	21 1/2"	546.500	21 3/4"	547.200
11 1/4"	289.825	289.825	21"	533.600	22"	559.200	22 1/4"	562.625
11 1/2"	292.125	292.125	21 1/2"	546.500	22 1/2"	572.125	22 3/4"	572.000
11 3/4"	299.200	299.200	22"	559.200	23"	584.800	23 1/4"	587.425
12"	304.800	304.800	22 1/2"	572.125	23 1/2"	597.725	23 3/4"	596.800
12 1/4"	314.625	314.625	23"	584.800	24"	610.000	24 1/4"	612.225
12 1/2"	317.500	317.500	23 1/2"	597.725	24 1/2"	622.925	24 3/4"	621.600
12 3/4"	324.000	324.000	24"	610.000	25"	635.600	25 1/4"	627.025
13"	330.200	330.200	24 1/2"	622.925	25 1/2"	648.500	25 3/4"	636.400
13 1/4"	339.425	339.425	25"	635.600	26"	661.200	26 1/4"	641.825
13 1/2"	343.025	343.025	25 1/2"	648.500	26 1/2"	674.125	26 3/4"	651.200
13 3/4"	350.000	350.000	26"	661.200	27"	687.000	27 1/4"	656.625
14"	355.600	355.600	26 1/2"	674.125	27 1/2"	700.000	27 3/4"	666.000
14 1/4"	364.225	364.225	27"	687.000	28"	712.800	28 1/4"	671.425
14 1/2"	368.500	368.500	27 1/2"	700.000	28 1/2"	725.725	28 3/4"	680.800
14 3/4"	373.600	373.600	28"	712.800	29"	738.600	29 1/4"	690.225
15"	381.200	381.200	28 1/2"	725.725	29 1/2"	751.500	29 3/4"	699.600
15 1/4"	389.025	389.025	29"	738.600	30"	764.400	30 1/4"	709.025
15 1/2"	394.125	394.125	29 1/2"	751.500	30 1/2"	777.325	30 3/4"	718.400
15 3/4"	398.400	398.400	30"	764.400	31"	790.200	31 1/4"	727.825
16"	406.400	406.400	30 1/2"	777.325	31 1/2"	803.125	31 3/4"	737.200
16 1/4"	413.825	413.825	31"	790.200	32"	816.000	32 1/4"	746.625
16 1/2"	419.325	419.325	31 1/2"	803.125	32 1/2"	828.925	32 3/4"	756.000
16 3/4"	423.200	423.200	32"	816.000	33"	841.800	33 1/4"	765.425
17"	427.600	427.600	32 1/2"	828.925	33 1/2"	854.725	33 3/4"	774.800
17 1/4"	434.625	434.625	33"	841.800	34"	867.600	34 1/4"	784.225
17 1/2"	439.000	439.000	33 1/2"	854.725	34 1/2"	880.500	34 3/4"	793.600
17 3/4"	443.600	443.600	34"	867.600	35"	893.400	35 1/4"	803.025
18"	451.600	451.600	34 1/2"	880.500	35 1/2"	906.325	35 3/4"	812.400
18 1/4"	459.025	459.025	35"	893.400	36"	919.200	36 1/4"	821.825
18 1/2"	463.600	463.600	35 1/2"	906.325	36 1/2"	932.125	36 3/4"	831.200
18 3/4"	468.400	468.400	36"	919.200	37"	945.000	37 1/4"	840.625
19"	476.800	476.800	36 1/2"	932.125	37 1/2"	957.925	37 3/4"	850.000
19 1/4"	484.625	484.625	37"	945.000	38"	970.800	38 1/4"	859.425
19 1/2"	488.800	488.800	37 1/2"	957.925	38 1/2"	983.725	38 3/4"	868.800
19 3/4"	493.600	493.600	38"	970.800	39"	996.600	39 1/4"	878.225
20"	502.400	502.400	38 1/2"	983.725	39 1/2"	1009.500	39 3/4"	887.600
20 1/4"	510.625	510.625	39"	996.600	40"	1022.400	40 1/4"	897.025
20 1/2"	515.200	515.200	39 1/2"	1009.500	40 1/2"	1035.325	40 3/4"	906.400
20 3/4"	520.000	520.000	40"	1022.400	41"	1048.200	41 1/4"	915.825
21"	529.600	529.600	40 1/2"	1035.325	41 1/2"	1061.125	41 3/4"	925.200
21 1/4"	537.625	537.625	41"	1048.200	42"	1074.000	42 1/4"	934.625
21 1/2"	542.000	542.000	41 1/2"	1061.125	42 1/2"	1086.925	42 3/4"	944.000
21 3/4"	547.000	547.000	42"	1074.000	43"	1100.000	43 1/4"	953.425
22"	556.800	556.800	42 1/2"	1086.925	43 1/2"	1113.125	43 3/4"	962.800
22 1/4"	565.625	565.625	43"	1100.000	44"	1126.200	44 1/4"	972.225
22 1/2"	570.400	570.400	43 1/2"	1113.125	44 1/2"	1139.325	44 3/4"	981.600
22 3/4"	575.600	575.600	44"	1126.200	45"	1152.400	45 1/4"	991.025
23"	585.600	585.600	44 1/2"	1139.325	45 1/2"	1165.500	45 3/4"	1000.400
23 1/4"	594.625	594.625	45"	1152.400	46"	1178.600	46 1/4"	1009.825
23 1/2"	599.600	599.600	45 1/2"	1165.500	46 1/2"	1191.725	46 3/4"	1019.200
23 3/4"	604.800	604.800	46"	1178.600	47"	1204.800	47 1/4"	1028.625
24"	614.400	614.400	46 1/2"	1191.725	47 1/2"	1217.925	47 3/4"	1038.000

DELRIN CONTACT  
RESIN

VARIOUS SEDES  
2016-LOAD CONTACT-2

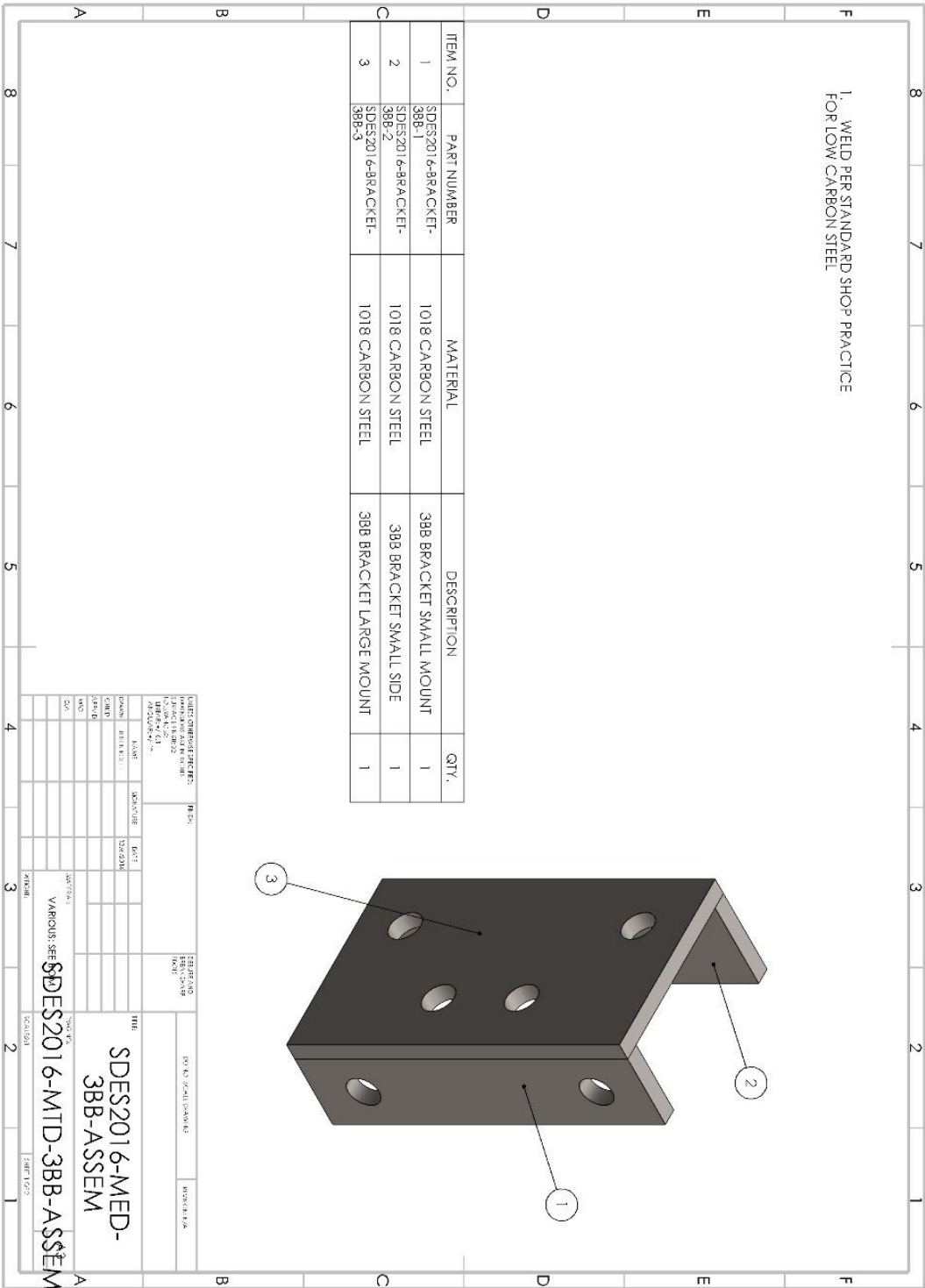
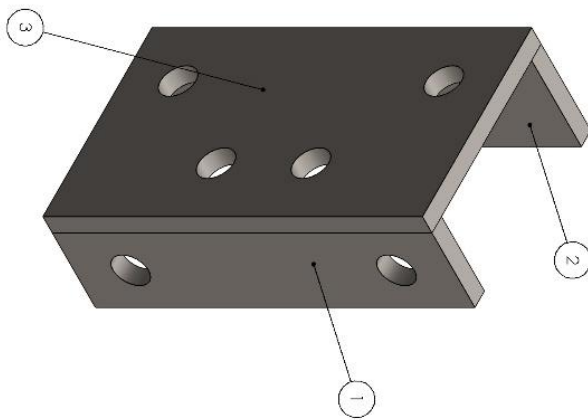






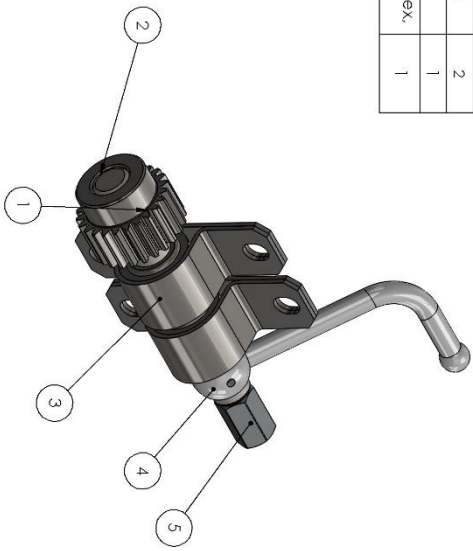
1. WELD PER STANDARD SHOP PRACTICE  
FOR LOW CARBON STEEL

ITEM NO.	PART NUMBER	MATERIAL	DESCRIPTION	QTY.
1	SDES2016-BRACKET-3BB-1	1018 CARBON STEEL	3BB BRACKET SMALL MOUNT	1
2	SDES2016-BRACKET-3BB-2	1018 CARBON STEEL	3BB BRACKET SMALL SIDE	1
3	SDES2016-BRACKET-3BB-3	1018 CARBON STEEL	3BB BRACKET LARGE MOUNT	1





ITEM NO.	PART NUMBER	MATERIAL	DESCRIPTION	QTY.
1	5172T34	STAINLESS STEEL	HT-LOAD MTR GEAR, 20°	1
2	1886K51	STEEL	BLACK OXIDE COATED SHAFT	1
3	7930K16	STAINLESS STEEL	VIBRATION DAMPING SLEEVE BRNG	2
4	6336K7	STAINLESS STEEL	HAND CRANK	1
5	LUG NUT	STEEL	Lug Nut, 1/2-20 UNF, 13/16 Hex, 11/16 x 3/4 Shank	1



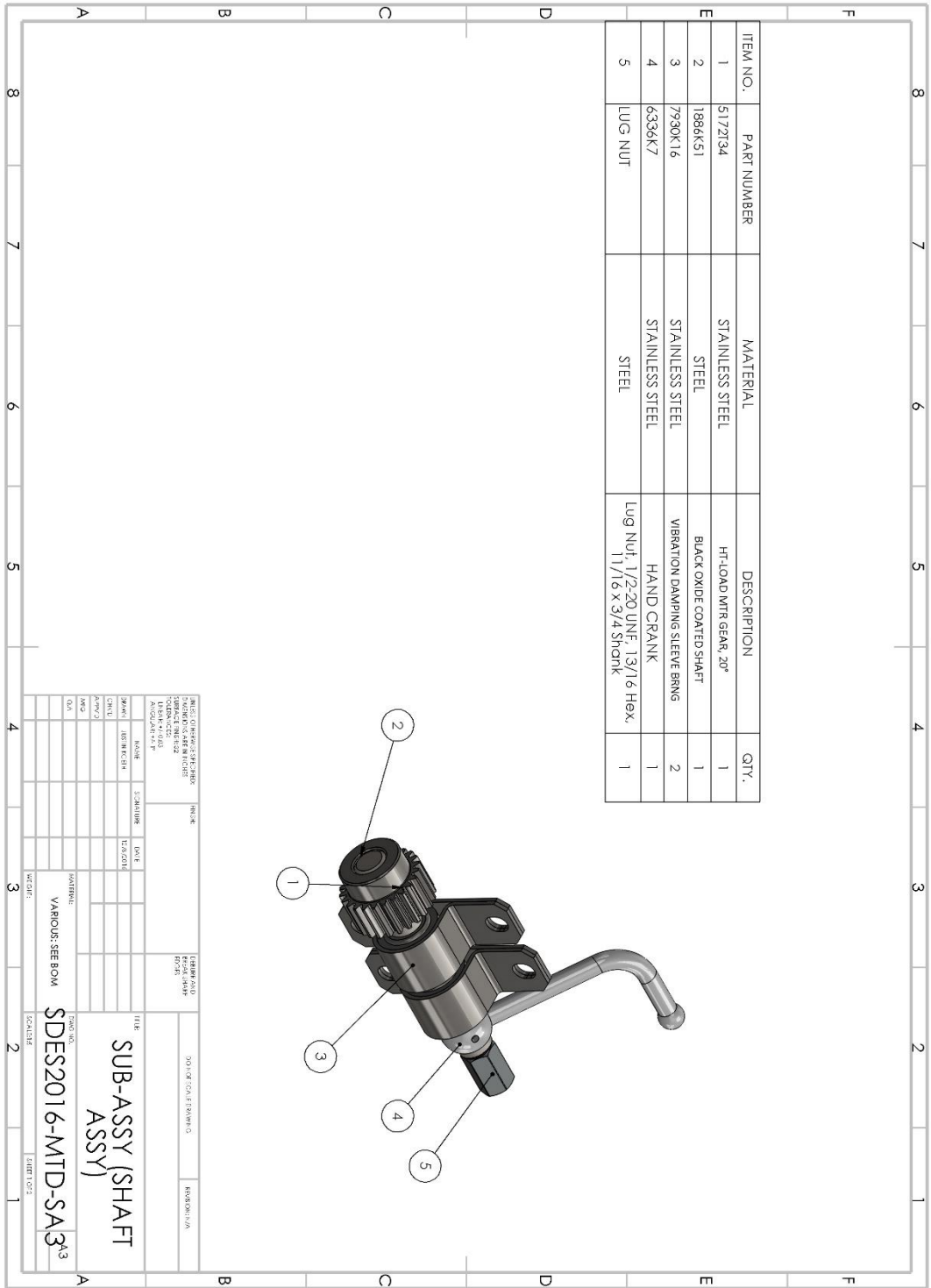
ITEM NO.	DESCRIPTION	QTY.	UNIT	REVISION	DATE	BY	CHKD	APP'D
1	HT-LOAD MTR GEAR, 20°	1	INCH					
2	BLACK OXIDE COATED SHAFT	1	INCH					
3	VIBRATION DAMPING SLEEVE BRNG	2	INCH					
4	HAND CRANK	1	INCH					
5	Lug Nut, 1/2-20 UNF, 13/16 Hex, 11/16 x 3/4 Shank	1	INCH					

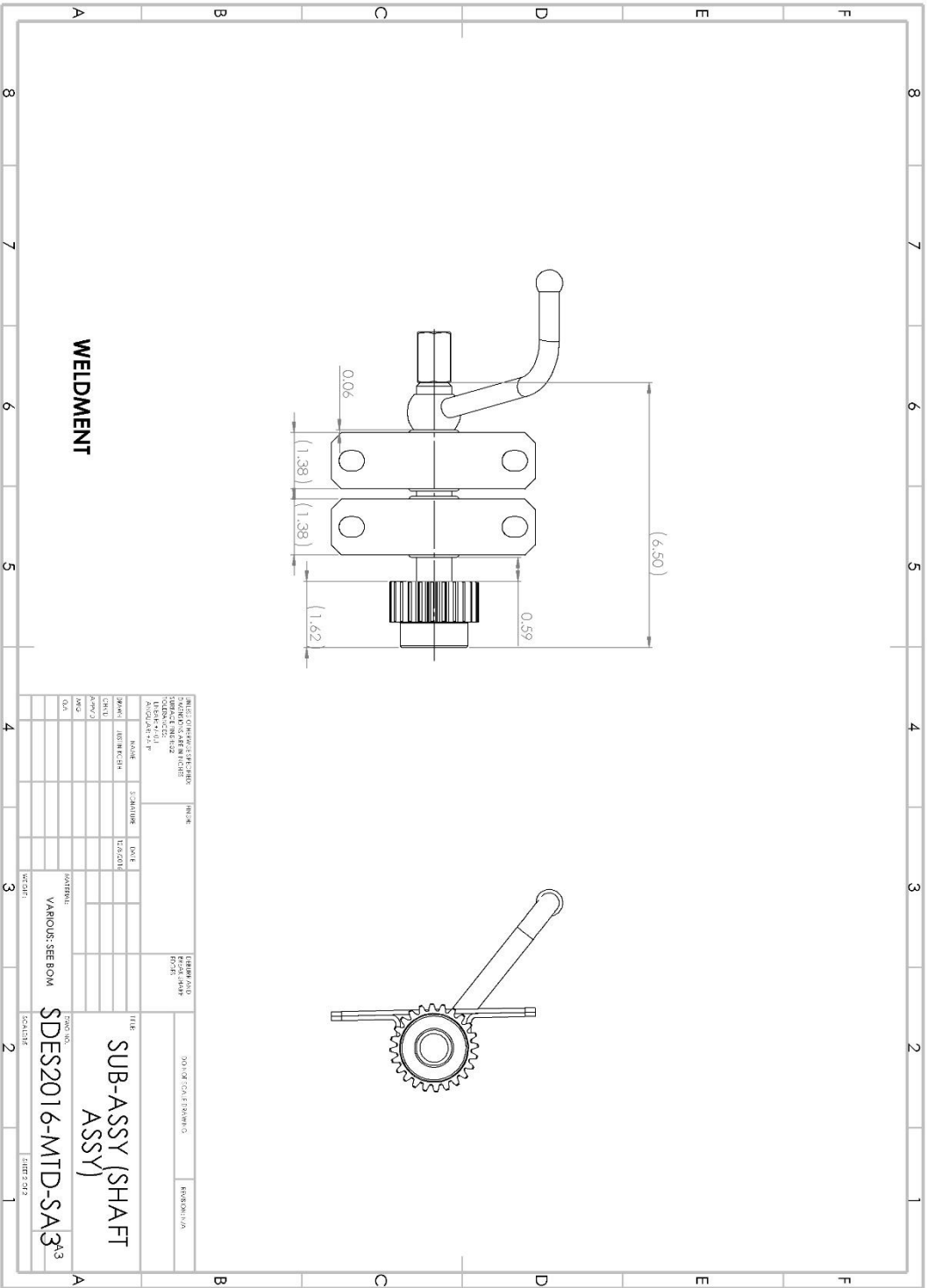
  

NAME	SCHEDULE	DATE	TIME
DATE	TIME	DATE	TIME
DATE	TIME	DATE	TIME
DATE	TIME	DATE	TIME

VARIOUS: SEE BOM

SDSS2016-MTD-SA3A3





## **APPENDIX J – PLAN FOR MANUFACTURING**

The majority of the raw materials to be used in manufacturing will be cut to size with a cutoff saw then fit up for fabrication and welded by a company that has the capability to weld aluminum structural members. All covers will be made out of sheet metal and will be waterjet/laser jet then bent to the drawing dimensions. Other processes such as drilling, necessary holes, milling brackets (if needed), will be completed by Justin at the machine shop at the Victory Parkway campus at the University of Cincinnati during hours with supervision. Paint and final assembly will also take place at the Victory Parkway campus.

## **APPENDIX K – PLAN FOR TESTING**

Testing for this senior design will incorporate a set of tests to design the most important factors associated with this design in terms of engineering characteristics. Briefly, these tests will include the setup time, lifting and lowering functionality, a designed static loading test, a designed fatigue loading test, and a complete road test. All testing will take place on a private roadway to ensure there are no safety issues, before moving to public roadways. A post visual examination and will be performed to ensure the devices remains in an operational manner.